PROCEEDINGS

AND

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XXI.

SESSION 1906-1907.

PRICE—TWENTY-ONE SHILLINGS.

LIVERPOOL:
C. TINLING & CO., LTD., PRINTERS, 53, VICTORIA STREET.

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PROCEEDINGS

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LIVERPOOL BIOLOGICAL SOCIETY.

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1887—88 J. J. DRYSDALE, M.D.
1888—89 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—90 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
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1891—92 T. J. MOORE, C.M.Z.S.
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1895—96 Prof. R. J. HARVEY GIBSON, M.A.
1896—97 HENRY O. FORBES, LL.D., F.Z.S.
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1898—99 Prof. C. S. SHERRINGTON, M.D., F.R.S.
1899—1900 J. WIGLESWORTH, M.D., F.R.C.P.
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1901—1902 HENRY C. BEASLEY.
1902—1903 R. CATON, M.D., F.R.C.P.
1903—1904 Rev. T. S. LEA, M.A.
1904—1905 ALFRED LEICESTER.
1905—1906 JOSEPH LOMAS, F.G.S.

SESSION XXI., 1906-1907.

President:

Prof. W. A. HERDMAN, D.Sc., F.R.S.

Vice-Presidents:

ALFRED LEICESTER.
JOSEPH LOMAS, F.G.S.

Hon. Treasurer:

W. J. HALLS.

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JAMES JOHNSTONE, B.Sc.

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Prof. SHERRINGTON, F.R.S.
L. R. THORNELY (Miss).

Representative of Students' Section:
W. DAKIN, B.Sc.

REPORT of the COUNCIL.

The past session has been a memorable one in the annals of the Society. In the first place, during this session the Society celebrated by a most interesting and successful function, its twenty-first year of work, and secondly, for the first time the student members of the Society organised themselves as a distinct section.

The "Coming of Age" celebration was held on January 25th, and took the form of a Scientific Conversazione (see "Proceedings," p. xi.) held in the Zoology buildings of the University. In addition to members of the Society and their friends, a number of representative citizens and many scientific men from other centres were invited, and took part in the proceedings. The Society is very much indebted to the distinguished visitors who so kindly brought interesting exhibits and delivered addresses, and at the next succeeding meeting of the Council the following resolution was passed:—"That the cordial thanks of the Council of the Society be accorded to Prof. Poulton, Mr. Stanley Gardiner, Prof. Cossar Ewart and Mr. R. C. Punnett for their great kindness in contributing so much to the interest of the function which was held in celebration of the coming of age of the Society."

Under the stimulating influence of Mr. Pearson and Mr. Douglas Laurie, an unusually large number of junior and senior students of the Zoology Department of the University joined the Society as student members, and, with the sanction of the Council, these members were organised into a "Students' Section," holding supplementary meetings under officials of their own electing, and

having a representative on the Council of the parent Society. The membership of the Students' Section is 48, and 11 meetings were held in addition to the ordinary meetings of the Society.

The communications made to the Society at the ordinary meetings have been representative of almost all branches of Biology, and the various exhibitions and demonstrations thereon have been of great interest.

The Library continues to make satisfactory progress, and additional important changes have been arranged.

The Treasurer's statement and balance-sheet are appended.

The members at present on the roll are as follows:—

Honorary members - - - - - -	8
Ordinary members - - - - - -	66
Associate members - - - - - -	3
Student members, including Students' Section -	60
Total - -	137

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the twenty-first session was held at the University, on Saturday, October 27th, 1906.

The President-elect (Prof. Herdman, D.Sc., F.R.S.) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1905-1906 (see "Proceedings," Vol. XX., p. viii.) was submitted and adopted.

2. The Treasurer's Balance Sheet for the Session 1905-1906 (see "Proceedings," Vol. XX., p. xviii.) was submitted and approved.

3. The following Office-bearers and Council for the ensuing Session were elected:—Vice-Presidents, Joseph Lomas, F.G.S., and Alfred Leicester: Hon. Treasurer, T. C. Ryley; Hon. Librarian, James Johnstone, B.Sc.; Hon. Secretary, Joseph A. Clubb, M.Sc.; Council, H. C. Beasley, R. Caton, M.D., W. J. Halls, Oulton Harrison, W. T. Haydon, W. S. Laverock, M.A., B.Sc., R. Newstead, F.L.S., J. H. O'Connell, L.R.C.P., Joseph Pearson, M.Sc., Alfred Quayle, and Professor Sherrington, F.R.S.

4. Professor Herdman delivered the Presidential Address on "Some Problems of the Sea" (see "Transactions," p. 1). A vote of thanks was proposed by Mr. Alfred Leicester, seconded by Dr. O'Connell, and carried with acclamation.

The second meeting of the twenty-first session was held at the University, on Friday, November 9th, 1906. The President in the chair.

1. Mr. H. C. Chadwick submitted the Annual Report on the work of the Liverpool Marine Biology Committee and the Port Erin Biological Station (see "Transactions," p. 21).

The third meeting of the twenty-first session was held at the University, on Friday, December 14th, 1906. The President in the chair.

1. Mr. C. Gordon Hewitt, B.Sc., submitted the L.M.B.C. Memoir on the anatomy and physiology of *Ligia oceanica* (see "Transactions," p. 65).

2. Mr. W. Dakin, B.Sc., gave a note on the swimming of Pecten from observations made at the Biological Station, Port Erin.

In celebration of the 21st session of the Society, a highly successful function, in the form of a Scientific Conversazione, was held in the University on January 25th, 1907. On the invitation of the President and Council, a large and distinguished gathering assembled, and was received by the President and Mrs. Herdman in the Museum of the Zoology Department. The guests included many leading citizens, representatives of the sister societies of the City and of Manchester, Chester,

Southport, and other towns, as well as distinguished representatives from the Universities of Oxford, Cambridge, Edinburgh, Belfast, Manchester, Sheffield, and London.

After the reception, a short meeting was held in the Theatre, where the President welcomed the guests and referred to the importance of the occasion. Short addresses of a congratulatory nature were given by Sir Charles Eliot, Vice-Chancellor of Sheffield University, Principal Dale and Professor Poulton, of Oxford. Dr. Caton, as a past-President of the Society, responded.

The following lecturettes and demonstrations were afterwards given:—By Mr. R. C. Punnett (Cambridge) on "The New Heredity." By Prof. Poulton, F.R.S. (Oxford), on "The most wonderful example of Mimicry in the world," illustrated by the electric lantern. By Prof. Cossar Ewart, F.R.S. (Edinburgh), Exhibition and Demonstration of Horses' Skulls recently dug up from a Roman camp. By Mr. J. Stanley Gardiner (Cambridge), Leader of the recent expedition in the Indian Ocean, on "The Seychelles," illustrated by the electric lantern.

The following Exhibitions were laid out in the various rooms, and were explained at intervals during the evening:—(Mr. J. Johnstone)—Marked fish, otoliths, bacteriology, models, &c. (Miss Allen)—Exhibition of books, and the Society's publications. Exhibition of original drawings and proof plates. Collections of Tunicata and Pearl Oysters. (Mr. Douglas Laurie)—Collection of Ceylon Crabs classified, with demonstration of dimorphic forms. Exhibition of Antarctic photographs by Mr. W. S. Bruce, Leader of the "Scotia" Expedition. (Mr. J. E. S. Moore)—Microscopic demonstrations of the maturation of the ovum. (Mr. Newstead)—Exhibit

illustrating Insects and Disease. (Mr. Pearson)—Exhibition of microscopic objects. (Mr. Dakin)—Incubation of Eggs, collection of Oceanic Oozes, &c.

The fifth meeting of the twenty-first session was held at the University, on Friday, February 8th, 1907. The President in the chair.

1. Prof. Herdman gave a short note on "A Further Problem of the Sea," dealing with the distribution of marine animals on the Maldive Islands and the coast of Ceylon.

2. Mr. J. Johnstone, B.Sc., submitted the Annual Report of the Investigations carried on during 1906 in connection with the Lancashire Sea Fisheries Committee (see "Transactions," p. 101).

The sixth meeting of the twenty-first session was held at the University, on Friday, March 8th, 1907. The President in the chair.

1. Mr. R. Douglas Laurie, B.A., communicated a paper on "Biometric Methods in relation to Evolution." A discussion followed.

2. The President submitted the L.M.B.C. memoir on "Antedon," by Mr. H. C. Chadwick (see "Transactions," p. 371).

The seventh meeting of the twenty-first session was held at the University, on Friday, May 10th, 1907. The President in the chair.

1. In the absence of Dr. O'Connell, the Secretary exhibited, with remarks, some of his interesting living reptiles.

2. Mr. J. Pearson, M.Sc., communicated a paper on "Ecdysis and Regeneration of lost limbs in Crustacea." An interesting discussion followed the reading of the paper.

The eighth meeting of the twenty-first session was the Annual Field Meeting held at Hilbre Island, on Wednesday, May 29th, in conjunction with the Manchester University Biological Society. At the short business meeting held after tea, on the motion of Professor Herdman from the chair, seconded by Dr. O'Connell, Mr. W. T. Haydon was unanimously elected President for the ensuing session.

LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

SESSION 1906-1907.

A. Ordinary Members.

(Life Members are marked with an asterisk.)

ELECTED.

1888 Beasley, Henry C., Prince Alfred Road, Wavertree.

1903 Booth, jun., Chas., 30, James Street, Liverpool.

1894 Boyce, Prof., University, Liverpool.

1889 Brown, Prof. J. Campbell, 8, Abercromby Square.

1886 Caton, R., M.D., F.R.C.P., 78, Rodney Street.

1886 Clubb, J. A., M.Sc., Hon. Secretary, Free Public Museums, Liverpool.

1902 Cowley, R. C., 6, Sandon Terrace, Liverpool.

1905 Cussans, Miss M., B.Sc., Edge Hill Training College, Liverpool.

1903 Dixon-Nuttall, F. R., Ingleholme, Eccleston Park, Prescot.

1902 Deacon, H. Wade, 8, Ullet Road, Liverpool.

1905 Drabble, Dr. Eric, Hartley Laboratories, University.

1886 Gibson, Prof. R. J. Harvey, M.A., F.L.S., University, Liverpool.

1902 Glynn, Dr. Ernest, 67, Rodney Street.

1903 Guthrie, Thomas, 8, Canning Street, Liverpool.

1886 Halls, W. J., Hon. Treasurer, 35, Lord Street.

1901 Hanna, W., M.A., M.B., 30, Marmion Road, Liverpool.

1896 Haydon, W. T., 135, Bedford Street S.
1886 Herdman, Prof. W. A., D.Sc., F.R.S., PRESIDENT, University, Liverpool.
1893 Herdman, Mrs. W. A., Croxteth Lodge, Ullet Road, Liverpool.
1897 Holt, Alfred, Crofton, Aigburth.
1902 Holt, A., jun., Crofton, Aigburth.
1903 Holt, George, 5, Fulwood Park, Liverpool.
1903 Holt, Richard D., 1, India Buildings, Liverpool.
1900 Horsley, Dr. Reg., Stonyhurst, Blackburn.
1904 Jenkins, J. T., D.Sc., Ph.D., Fisheries Office Preston.
1898 Johnstone, James, B.Sc., HON. LIBRARIAN, University, Liverpool.
1903 Jones, Sir Alfred L., African House, Water Street.
1886 Jones, Charles W., Allerton Beeches, Liverpool.
1903 Jones, Dr. Robert, 11, Nelson Street, Liverpool.
1894 Lea, Rev. T. S., M.A., Leek Vicarage, Kirkby Lonsdale.
1886 Leicester, Alfred, VICE-PRESIDENT, 148, Liscard Road, Liscard.
1896 Laverock, W. S., M.A., B.Sc., Free Museums, Liverpool.
1906 Laurie, R. Douglas, B.A., University, Liverpool.
1886 Lomas, J., F.G.S., VICE-PRESIDENT, 13, Moss Grove, Birkenhead.
1905 Moore, J. E. S., 25, Croxteth Road, Liverpool.
1905 Moore, Prof. B., University, Liverpool.
1905 Mountmorres, The Hon. Viscount, Institute of Tropical Research, The Museum, Liverpool.
1904 Newstead, R., A.L.S., School of Tropical Medicine, Liverpool.
1888 Newton, John, M.R.C.S., 2, Prince's Gate, W.
1900 Nisbet, Dr., 7, Croxteth Road, Liverpool.

1904 O'Connell, Dr. J. H., 38, Heathfield Road, Liverpool.
1904 Pallis, Miss M., Tätoi, Aigburth Drive, Liverpool
1894 Paterson, Prof., M.D., M.R.C.S., University, Liverpool.
1894 Paul, Prof. F. T., Rodney Street, Liverpool.
1905 Pearson, J., M.Sc., Zoological Department, Liverpool.
1903 Petrie, Sir Charles, 7, Devonshire Road, Liverpool.
1897 Quayle, Alfred, 7, Scarisbrick New Road, Southport.
1903 Rankin, J., 67, South John Street, Liverpool.
1903 Rathbone, H. R., Oakwood, Aigburth.
1903 Rathbone, Herbert R., C.C., 15, Lord Street, Liverpool.
1890 *Rathbone, Miss May, Backwood, Neston.
1887 Ryley, Thomas C., 10, Waverley Road.
1894 Scott, Andrew, Piel, Barrow-in-Furness.
1895 Sherrington, Prof., M.D., F.R.S., University, Liverpool.
1886 Smith, Andrew T., 5, Hargreaves Road, Sefton Park.
1895 Smith, J., F.L.S, Hood Lane, Sankey Bridge, Warrington.
1903 Stapledon, W. C., 2, Marine Park, West Kirby.
1903 Thomas, Dr. H. Wolferstone, School of Tropical Medicine, Liverpool.
1903 Thomas, Dr. Thelwall, 84, Rodney Street, Liverpool.
1905 Thompson, Edwin, 1, Croxteth Grove, Liverpool.
1889 Thornely, Miss L. R., Nunclose, Grassendale.
1903 Timmis, T. Sutton, Cleveley, Allerton, Liverpool.
1888 Toll, J. M., 49, Newsham Drive, Liverpool.

1903 Walker, Horace, South Lodge, Princes Park.
1891 Wiglesworth, J., M.D., F.R.C.P., County Asylum, Rainhill.
1896 Willmer, Miss J. H., 20, Lorne Road, Oxton, Birkenhead.

B Associate Members.

1903 Tattersall, W., B.Sc., Marine Lab., Moyard, Letterfrack, Co. Galway.
1905 Harrison, Oulton, Denehurst, Victoria Park, Wavertree.
1905 Carstairs, Miss, 39, Lilley Road, Fairfield.

C Student Members.

Adams, A., Zoological Department, University.
Arnett Dear, A., Edgeworth, Bebington.
Bishop, G. S. A., 4, Richmond Terrace, Everton.
Bramley-Moore, J., 138, Chatham Street.
Clothier, H. M., Zoological Department, University.
Greenwood, Miss F. V., Edge Hill Training College, Durning Road.
Hannah, J. H. W., 55, Avondale Road, Sefton Park.
Hudson, Miss K. B., University Hall, Beech Street.
Ponsonby, Miss F., Edge Hill Training College, Durning Road.
Scott, Miss D., University Hall, Beech Street.
Shipperbottom, Miss L., Edge Hill Training College, Durning Road.
Summers, Miss B., Edge Hill Training College, Liverpool.

University Students' Section.

Chairman: W. Dakin, B.Sc.
Hon. Secretary: J. Davidson.

Members:

Misses A. Nicholls, A. Owen, E. Hirst, D. Moss, M. C. Mandale, E. Stopford, M. Hodgkinson, A. Prescott, E. Mathewman, A. Kenyon, K. Winston, G. Mitchell, M. Cheetham, E. Bury, M. K. Kaye, M. L. Whitehurst, M. K. Johnston, W. Herdman, and E. Norris.

Messrs. J. A. Griffiths, J. D. Webb, R. W. Gemmell, F. G. F. Browne, H. Nield, N. Laing, R. Heald, R. Kennon, A. Williamson, J. Davidson, H. V. Forster, A. L. Oluwole, T. Hayhurst, R. H. Knowles, C. A. Bernard, M. T. Morgan, D. H. Clarke, E. E. Billington, C. Kennedy, R. C. Crooke, S. N. Wright, H. Jones, J. Loudon, W. Parry, H. G. Roberts, F. A. Martin, E. V. Pedlar, M. Pallis, and A. Holmes.

D Honorary Members.

S.A.S., Albert I., Prince de Monaco, 25, Faubourg St. Honore, Paris.

Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.

Claus, Prof. Carl, University, Vienna.

Fritsch, Prof. Anton, Museum, Prague, Bohemia.

Giard, Prof. Alfred, Sorbonne, Paris.

Haeckel, Prof. Dr. E., University, Jena.

Hanitsch, R., Ph.D., Raffles Museum, Singapore.

Solms-Laubach, Prof.-Dr., Botan. Instit., Strassburg.

THE LIVERPOOL BIOLOGICAL SOCIETY.

Dr. IN ACCOUNT WITH W. J. HALLS, HON. TREASURER. **Cr.**

Dr.	£	s.	d.	Cr.	£	s.	d.
1906, Oct. 1st to Sept. 30th, 1907.				1906, Oct. 1st to Sept. 30th, 1907.			
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	£92	19	8		£92	19	8

Audited and found correct,
JOSEPH LOMAS.

LIVERPOOL, *October 1st, 1907.*

Dr. STATEMENT OF ACCOUNTS OF STUDENTS' SECTION, *per* W. J. DAKIN. **Cr.**

Dr.	£	s.	d.	Cr.	£	s.	d.
To Teas, Sundries, &c.	2	8	6	By 33 Subscriptions at 2/6	4	2	6
,, Balance handed to Hon. Treasurer	7	14	0	,, Grant (Guild of Undergraduates)	6	0	0
	£10	2	6		£10	2	6

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

ADDRESS

ON

SOME PROBLEMS OF THE SEA.

By Professor W. A. Herdman, F.R.S., President.

(Read 26th October, 1906.)

I beg to acknowledge, with proper gratitude, the honour you have done me in electing me once more to the Presidential chair of our Society. You are aware that at the end of the present session we attain our majority. Our meeting next January will be the twenty-first since the Society was founded; and, as the senior surviving past-president, it was perhaps appropriate that I should be asked to re-occupy the chair for the occasion. As I desire to ask the Council to allow me later in the session to arrange a suitable celebration of our twenty-first year of work, I shall not occupy your time further now with remarks which may be more appropriate to that occasion.

I have already given two Presidential Addresses to this Society, and on thinking of what might be suitable matters to occupy you with on this third occasion I decided that it might be well, in place of taking one specific subject, to deal with two or three general questions of wide interest to all biologists, I hope, and possibly to others outside our bounds. That leads me to ask—Why are there not more *within* our bounds? This Society is too small. When we consider the wide scope and the deep interest of biological investigations, and their practical importance to mankind in connection with food supply and the public health—in addition to many industries, such as that of the oriental pearl, which enriches man by enhancing the beauty of woman—when

we remember that this Society embraces every branch of Zoology, Botany, Physiology, Palæontology, Geographical Distribution and many Practical Applications of these subjects, it is distinctly disappointing to find that the vast population of Liverpool yields us less than a hundred members.

The scientific man likes to think that all things can be explained—sooner or later; and probably the explanation of this curious circumstance is simple enough, but involves several reasons. The reason that prevents one man who would be interested in our meetings from joining us is not the reason that deters another. Leisure time for science in the lives of those who have other professions is, with the multifarious pursuits of modern life, more limited than it used to be. We all have many engagements and more or less urgent calls upon our spare time and surplus energy, which become more exacting as we get on in life. Other more special societies—Entomological, Conchological, Geological, Microscopical—call off some who would otherwise cast in their lot with us, and who find that time is too short for both series of meetings. Some have the mistaken idea that biology is too deep and uninteresting for any but the specialist, and that our proceedings may be learned but are dull. Biology is only as deep as the nature it studies, and that is of all depths, and it is interesting to every naturalist who loves any or all sides of nature; and, as for our methods here, they are in the hands of our members, and those of us who have been longest on the Council will rejoice the most at seeing more of our younger members playing a more active part in the affairs of the Society.

But I believe a far more potent reason than those I have given is simply that we are not known. I believe that there are hundreds, possibly thousands, in these parts

of Lancashire and Cheshire who would be sufficiently interested in at least some of our meetings—no one need pretend to be equally interested in all—to receive intellectual pleasure and stimulus if they only knew of the existence and work of our Society. The terms of membership ought to be made as easy as the Council can devise, the proceedings at our meetings ought to be made as instructive and interesting as Science knows how, and then every man and woman who studies, or wishes to study, or cares about advancing the study of, any branch of Natural Science—including what is called "Nature-Study"—ought to join our ranks and take part in our work. It lies with our present members to enlarge our bounds and to draw others within the fold. I appeal with confidence to you all to bring your friends to the meetings, and, if they are interested, to propose them as members, and to make the Society and its work known in any way that presents itself.

Finally, I appeal for more young members. All biologists are young in spirit. The study of nature keeps them young, or, if they have only taken to it late in life, it makes them young again. When I think of the young men I have known of mature age—such as the late Dr. David Robertson, "the naturalist of Cumbrae," who came dredging with some of us on the West Coast of Scotland in his 86th year, and was as keen and useful as the youngest and best of us—I am sorry for the prematurely aged persons of few years, but many cares, who have no interests beyond their business and, it may be, a football match or the golf links. A "hobby" is the saving of many both in their physical and their mental health, and no hobby is so conducive to health, sanity and happiness as devotion to some branch of Natural Science.

The advantage of biology as a science for

the amateur is that you can sub-divide it as much as you like, and still study your fraction in an intelligent manner. Years ago one of the amateur naturalists of Liverpool devoted his leisure to the special study of the common cockroach, but after some time he found his subject too large and had to restrict his attention with increased interest to one of the markings upon the head of that complex animal. That may be regarded as an extreme case, but, to take other examples, the study of Foraminifera, of Molluscan Shells, of Zoophytes and of Polyzoa, of Copepoda or of some group of Insects, is a subject large enough as a serious "hobby" for any man or woman. I need hardly say that such an amateur naturalist may do very good work and make valued additions to science. It is one of the glories of British Marine Biology that so much has been discovered and so many of our best monographs written, not by professional men, but by serious amateurs—men who have devoted the leisure of busy lives to the study of some branch of the subject as a hobby. I should like to see more young men and women come forward as members of this Society and become practical Naturalists. Those of us who are older and have had, so far, more experience of nature and methods will be only too thankful to help them at the beginning, then to work with them, and finally to learn from them.

I have just mentioned "methods," and one of the first methods to learn is the method of collecting the organisms you wish to study; and that brings me to the second part of this address, in which I wish to lay before you for consideration some questions in connection with methods of collecting in Marine Biology which I have had occasion to think about of late years.

The methods of collecting you adopt will, of course, depend upon your object in collecting. If you want large numbers of specimens you will adopt one method, and you will collect when, where and how you find you can get the greatest abundance. If, on the other hand, you want as many kinds as possible, you will adopt most varied methods, now one and now another, and you will collect in a very different manner in the different seasons and localities. But, so far, you will only get what may be called qualitative results, and that is what most naturalists have been content with in the past. Edward Forbes, the pioneer of dredging in this country, Wyville Thomson, the leader and hero of the "Challenger" expedition, Alder and Hancock, Carpenter and Jeffreys, Hincks and the Bradys, the well-known authors of our most authoritative works on marine biology, have all collected in the manner I have indicated above and have recorded qualitative results only. They have told us, in their monographs and reports, about the various kinds of animals found, but have only given vague indications of the relative abundance, of the seasonal variations, of the topographical distribution and of the bionomics of their environment.

Is any other kind of result attainable by collecting methods? That is one of the most important and fundamental questions which the marine biologist of the present day has to consider. When the application of marine biological enquiries to the problems of the fishing industries came to be investigated it was realised that a quantitative knowledge of such organisms as constitute the food, the enemies and the fellow competitors of our marketable fishes was desirable if not essential. Of these matters we then were, and still are, very ignorant. Lord Onslow, our first Minister of Fisheries, in opening, a year

ago, these Laboratories in which we are now assembled, alluded to the absence of exact knowledge of the subject which he found on taking office as President of the Board of Agriculture and Fisheries. Of course, isolated facts of a quantitative nature had become known and were accumulating, but there was no organised body of quantitative data such as would suffice to guide a policy or lead to definite conclusions on many fishery questions.

As an unimportant example of such an isolated observation we may take the fact that about twenty millions of the minute organism *Ceratium tripos* may be eaten in one day by the sardine on the French coast. No doubt every fact in science is of some value, and will one day find its place in the completed scheme of knowledge. But as a single observation unrelated to other facts this is of comparatively little value, except in so far as it suggests to us how important it might be to find out when, where and why the Ceratium becomes available as food for the sardine, where it comes from, and why it is sometimes absent. Many attempts have been made of recent years to answer such questions by obtaining quantitative information as to the distribution of organisms in the sea. The most noteworthy example of such work is that done by the German "plankton" naturalists, such as Hensen, Brandt, Lohmann and Apstein, at first under the well-known "Kiel Commission," and latterly in connection with the International exploration of the North Sea. These investigators, and especially Professor Hensen, deserve the greatest credit, not only for the central idea of organising and employing such means as would give exact quantitative results, but also for the ingenuity with which they have devised and worked out the details of the necessary methods and instruments. They have invented deep-water tow-nets, the silk of which

is shaped in accordance with mathematical formulæ to ensure the most efficient proportions. They have calculated filtration co-efficients applicable to each kind of silk employed, in its various conditions. They have elaborated apparatus for filtering, measuring and analysing the results of the catch. They have made series of observations in fresh-water lakes and in some parts of the ocean, and from the samples so obtained they have drawn conclusions as to the population and the cyclical changes of matter in the sea of a very wide-reaching nature.

Dr. J. Travis Jenkins, some five years ago, gave an account to this Society of the "plankton" work as carried out by the Germans in the North Sea and the Baltic, and on that occasion he said: "It is to be hoped that the Irish Sea may be subsequently investigated in like manner. A comparison with the results already obtained from the North and Baltic Seas could not fail to be of interest and to yield important results." (Trans. L.B.S., Vol. XV., p. 280.) For several years I have been trying to get such work carried out in connection with our local sea-fisheries investigations; but, although everyone concerned is sympathetic and helpful, it is difficult to get any new work, however important, undertaken on board a steamer that cannot, because of administrative duties, be wholly devoted to scientific investigation. A Hensen plankton net has now been obtained for the fisheries steamer, but is not yet being systematically used. It was partly because of this difficulty that I decided to charter a small steamer myself for a couple of months this summer and then made the series of trials of plankton nets at Port Erin which I shall tell you about presently.

But let me first give you some idea of the problems in the economics of the sea, which Hensen and his fellow-

workers undertake to solve by means of their system of plankton observation. From a series of 120 observations in the Eckenförde district of the West Baltic, Hensen concluded that from January to April, over an area of about 16 square miles, there are in all 370 eggs of cod and flat fish per square metre of surface. He also calculates that the fish caught in the same district would, if left in the sea, produce 110·6 eggs per square metre, and the relation between these two totals shows that the fishermen capture in that district about one-fourth of the fish population annually. It is obvious that the correctness of this conclusion depends entirely upon how far the 120 original observations were truly representative of the 16 square miles of sea fished.

As the result of three series of 49, 50, and 59 catches respectively, made in the North Sea in 1895, Hensen and Apstein computed that the North Sea contained that season, in its surface waters, 157 billions of fish eggs. Here the quantity in the 547,623 million square metres of the North Sea has been estimated from 158 sample-catches, and from our knowledge of the average number of eggs produced annually by each kind of fish, it is stated that we can arrive at the actual number of mature food fishes of the North Sea—a colossal conclusion to base upon such a small number of samples as 158—only one for each 3,465,968,354 square metres of surface.

From certain samples obtained from the West Baltic it has been calculated that every square mile contains 80 to 100 billion Copepoda, and from the relative proportions of eggs, larvæ and adults it is deduced that for the 16 square miles of the fishery district the annual consumption of Copepoda must be 15,600 billions; and that consequently that district supports Copepod food sufficient for 534 million herring of average size.

Nothing in the economics of the sea could be more important than such conclusions if we could feel certain that they are correct, or even that they are reasonable approximations, for, of course, in dealing with such very large numbers it is not possible, and it is not necessary, to have absolute accuracy.

These elaborate and highly ingenious methods of Hensen and his school, devised both to capture and to estimate the living contents of the sea, have naturally been subjected to a certain amount of criticism. This has appeared chiefly in Germany and in the United States, and a fair example is seen in Professor Kofoid's paper "On Some Important Sources of Error in the Plankton Method" (see "Science" for Dec. 3, 1897).*

It has been pointed out by Kofoid and others that the net does not, as a matter of fact, filter the whole of a column of water through which it passes; a part of the water is pushed aside. There is for every net—probably for every net on every occasion when it is used—a co-efficient by which the result must be multiplied. It is difficult enough to determine this co-efficient (some number such as 1·32, which has sometimes been used) when all the factors in the case are known, but even when it has been correctly determined for a special form of net and mesh of silk it must not be assumed that it will remain constant. On the contrary, it will vary with the rate at which the net is hauled and with any current tidal or other in the water; and, furthermore, there are two changes which take place in the mesh of the net that will affect it, viz., shrinkage with use and clogging with

* See also his "Plankton of the Illinois River" in Bull. Illin. State Lab. Nat. Hist., vi., Nov. 1903, where Kofoid explains why he relinquished the Hensen and Apstein nets for the pump-plankton method.

particles organic and otherwise. Kofoid finds that from shrinkage alone the area of the openings in a square centimetre may decrease 50 per cent.

A difficulty of quite another kind that has been pointed out by various critics is that small as the meshes of the silk are, many of the minuter organisms of the plankton pass through and are lost. Kofoid has determined the percentage of loss from this source for certain organisms, *e.g.*, he finds that "of *Codonella* as many as 21 individuals may escape to one retained."

But these difficulties, serious as they may seem, and as they are regarded by some, may still be to a considerable extent overcome by taking precautions and by applying corrections to the result. They are troublesome difficulties, but they are not, to my mind, fatal. They only make the work more difficult, more expensive, and more slow. They may still, after all corrections have been applied, allow of a fair approximation to a correct quantitative estimate of the organisms present in the particular sample of water through which the net has been pulled. But can we safely apply the results so obtained to any further purpose? This brings me to my main difficulty—a difficulty I have felt for many years, but which was forcibly brought before me in my observations at Port Erin during the present summer. It is a fundamental assumption (principle I think it is sometimes called) in the Hensen method, that the organisms are distributed with such uniformity over wide areas of the sea that, after taking some samples per square metre, it is considered justifiable to multiply up by the number of square metres in a fishing district, or even in the wide extent of the Baltic or the North Sea. Here we have evidently a most fundamental point upon which the stability of the entire superstructure depends. If your

samples are not sufficiently representative, if your observations are liable to be affected by any accidental factor which does not apply to the entire area, then your results may be so erroneous as to be useless or worse than useless, since they may lead to deceptive conclusions.

Let us examine this assumed uniformity of the plankton. It is a common experience of all naturalists who have tow-netted much on the surface of the sea, that many of the commonest organisms occur in swarms, and that neighbouring areas of water may differ very much in density of population and may also change greatly from day to day. Many such cases are recorded in the literature of biology, in the Reports of the "Challenger" expedition, and elsewhere, but I may add here a few observations of my own. On the West Coast of Scotland I have seen large Copepoda so abundant for a mile or two that they seemed from the deck of a yacht to be dancing in crowds in the water. On stopping the boat and taking a gathering with the net they were found to be *Calanus finmarchicus*. In a few minutes we passed out of the swarm. Consequently, two sample gatherings taken a mile apart would, on this occasion, have given totally different results. On our L.M.B.C. expeditions in the Irish Sea we have on many occasions noticed and recorded the very irregular distribution of *Anomalocera patersoni*. On one occasion, in the North of Norway, I got in a short haul of the surface tow-net a phenomenal amount of the bright red northern form of *Calanus finmarchicus* so much, in fact, that after filling various jars, some of which are still in our Museum, we cooked and ate the remainder. We took tow-nettings in various other places to the north and south, but never got another such haul.

And this irregularity in distribution does not apply to

Copepoda alone. To take an example from the lower marine plants:—In the Red Sea and on various occasions in the Indian Ocean I have seen *Trichodesmium erythraeum* forming a most conspicuous red-brown or tawny yellow-brown scum on the surface of the sea for, it might be, a few hundred yards up to a mile in width, and several or even many miles in length, while the sea at each side of the patch was entirely free from the organism. Under these circumstances, and I believe them to be the most usual circumstances, a sample taken in the Trichodesmium area, or possibly two successive samples taken by a vessel running along the length of the tract, would give enormous numerical results, while if the samples had been taken a mile away the conclusions arrived at as to the prevalence and importance of the organism might have been very different. *Noctiluca miliaris*, again, is very local in its distribution. Occasionally, during recent years, I have taken it in abundance in late summer off the North Coast of Anglesey, while Mr. Chadwick, tow-netting at the same time at Port Erin, only 50 miles distant, across the same sea, has not been able to find a single specimen.

Before turning to my observations at Port Erin this summer, let me direct attention to the results obtained by Dr. Herbert Fowler in his expedition in the North Atlantic in the summer of 1900—a cruise which has thrown much light upon the relations of oceanic plankton. Dr. Fowler's results are very valuable in demonstrating the varied composition of the plankton from day to day in the open sea. His sixteen stations were so close together that the whole area investigated measured only 66 miles by 22, and his results for the Chaetognatha show that even at adjacent stations on successive days the numbers obtained were very different, one catch being

many times another, and the greatest about 30 times as much as the least. Now, if a vessel taking observations, say, 20 miles apart, were to have traversed this area and obtained only one of these gatherings, she might have gone off with a so-called sample which was ten or twenty times too great or too small to represent fairly the average, in either case giving an indication that was false and might lead to entirely erroneous conclusions. Similarly in the case of *Doliolum*, Dr. Fowler found an enormous disproportion between the amounts of the catch on the different days, even at closely adjacent localities. It is obvious that if the number of *Doliolum* present in the area were calculated from one of his samples (such as No. 8) the result would be entirely different from that based upon other samples (such as Nos. 24 and 25). Cases of this kind could be multiplied, and have no doubt occurred in the experience of most naturalists who have done much work at sea. And it was the knowledge of such cases that induced me this summer to devote the vacation almost wholly to making successive plankton hauls day after day in a limited area of the open sea off Port Erin, for the purpose of comparing days, nets, and depths with one another.

I chartered a small steamer, which proved fairly well suited for the purpose, and cruised mainly between Port Erin and the Calf Island. Nearly 80 gatherings were taken in about 40 days, and I used in all five different nets, all made of fine miller's silk. These were:—

A Hensen closeable net of 200 meshes to the inch;

A small Apstein net of 212 meshes to the inch;

An open tow-net, weighted, 120 meshes to the inch;

An open surface tow-net, 120 meshes to the inch, new;

And an open surface tow-net, 120 meshes to the inch, one season old.

The Hensen closeable net (Petersen's modification) and the weighted open net were lowered to about the same depth, but gave, when worked together for the same time, in most cases very different results. The two open surface nets (old and new) were worked side by side, and although they were of exactly the same size, and differed only in the age of the silk of which they were formed, the catch was in most cases very different. These differences were on some occasions obvious to the eye when the net was emptied on board ship; but all the gatherings, carefully preserved by Mr. Chadwick, have since been measured and worked over by Mr. Andrew Scott, who has kindly supplied me with his detailed lists. It is from these that I quote the following examples.

The gatherings varied in quantity from 0·5 to 40 c.cm., although all were as nearly as possible 15 minutes' hauls. In some cases the plankton seemed to be fairly evenly distributed between surface and deeper waters, while on other days great differences existed, *e.g.*, off the Calf Island, on August 10th, the surface net and the net towed at seven fathoms gave the same amount of material; while at the same spot, on August 13th, the surface net gave 8 c.cm. and the net at ten fathoms 32 c.cm., and the following day, at the same spot again, the surface net had only 3·5 c.cm. and the net at ten fathoms 40 c.cm.

Even in cases where the surface and deeper hauls were not very different in quantity, a marked difference in quality was sometimes visible to the eye at the time, and this has since been corroborated by Mr. Scott's examination, *e.g.*, on August 31st, off the Stack of Calf, surface, 8 c.cm.; five fathoms, 13 c.cm.; ten fathoms, 14 c.cm. Mr. Scott remarks:—"Larger number of

organisms at bottom, but variety not so great; *Acartia* and *Oithona* common all through; *Anomalocera* and *Centropages* and Crab Zoea at surface only; *Calanus, Paracalanus* and *Pseudocalanus* more plentiful in the deeper water than at surface." Again, on August 24th, three miles west of Bradda Head, Mr. Scott remarks:—"It is evident from the two (surface) collections that there was a difference in the organisms even in a very small space. A marked difference is discernible between the surface and ten fathoms." Throughout these gatherings *Oithona* seems to be mainly a surface Copepod and *Temora* mainly a deeper form; *Anomalocera* is chiefly on the surface, and *Calanus* more abundant in the deeper nets. *Sagitta* is more abundant below than at the top. Although in many cases the deeper gathering was larger than the surface one with the same net, this was not invariably the case as the following examples show:—

Aug. 24th.—Surface, 8 c.cm.; 5 faths., 19 c.cm.

Aug. 27th.—Surface, 11 c.cm.; 5 faths., 8·5 c.cm.; 10 faths., 5 c.cm.

Aug. 28th.—Surface, 13 c.cm.; 10 faths., 9 c.cm.

Sept. 6th.—Surface, 6 c.cm.; 10 faths., 0·5 c.cm.

Sept. 7th.—Surface, 16 c.cm.; 5 faths., 6 c.cm.; 10 faths., 3 c.cm.

A fuller account of these details will be laid before the Society on some future occasion in connection with either the Port Erin Report or the Fisheries Laboratory Report; but even without Mr. Scott's analysis of the preserved material there was abundant evidence, to those who saw the catches taken, that the plankton was very unequally distributed over the depths, the localities and the dates. It was clear that one net might encounter a swarm of some organism which a neighbouring net escaped, and that a sample taken on one day might be

very different in quantity from a sample taken under the same conditions next day.

I stopped this series of observations on September 17th. After a few days of wind a spell of quiet, calm weather followed, during which I took some tow-nettings both inside Port Erin Bay and outside, both in the day and at night, and all of these differed entirely in character from the gatherings of the previous weeks—being composed mainly of *Chætoceros* and other Diatoms. During this period of calms and light Easterly winds the surface of the sea was smooth and the water was distinctly coloured by the abundance of diatoms. When the weather broke again, at the end of September, another abrupt change took place, and gatherings taken at the beginning of October showed very few diatoms and many Copepoda. It is evident that if any observer had been taking quarterly or even monthly samples of the plankton in that sea-area he would have obtained very different results, according to the exact date of his visit. On three successive weeks at the end of September he might have found evidence for as many different far-reaching views as to the composition of the plankton in that part of the Irish Sea. How it can be supposed that hauls taken miles apart and repeated only at intervals of months, or even weeks, can give any sure foundation for calculations as to the population of wide sea areas, I fail to see. You must not suppose, however, that I fail to appreciate the labours of the plankton school at Kiel, or that I am at all hopeless as to science attaining to a more exact knowledge of the populations of the oceans. I consider that the leading idea is a good one, that the implements devised are very ingenious, and that the long-continued laborious computations of some of the German professors have been most praiseworthy. But I regard the method as still open

to serious objections, the most fundamental of which, to my mind, is the obvious irregularity in the distribution of the plankton horizontally, vertically, and chronologically—an irregularity which must vitiate any calculations based upon comparatively few and distant samples. I am distinctly of opinion that marine biologists ought to concentrate their efforts upon the intensive study of small areas before trying to estimate the contents of an ocean or even of a fishery district. Until we understand more fully the plankton of Port Erin, of Plymouth Sound, of the Firth of Forth, or of the Bay of Kiel, it is premature to attempt the North Sea or the Atlantic Ocean. The conclusions to which I have come do not lead me to be discouraged as to the ultimate success of scientific methods in solving what may be called world-wide problems, but they suggest that it might be wise to secure by detailed local work a firm foundation upon which to build, and to ascertain more accurately the representative value of our samples before we base conclusions upon them.

I do not doubt that in limited, circumscribed areas of water, in the case of organisms that reproduce with great rapidity, the plankton becomes more uniformly distributed, and a comparatively small number of samples may then be fairly representative of the whole. That is probably more or less the case with fresh-water lakes; and I have noticed it in Port Erin Bay in the case of diatoms. In spring, and again in autumn, when suitable weather occurs, as it did this year in the last week of September, the diatoms may increase enormously, and under such circumstances they seem to be very evenly spread over all parts and to pervade the water at all depths; but that is emphatically *not* the case with the Copepoda and other constituents of the plankton.

Since my return from Port Erin, and, in fact, since these notes were written in outline, I have noticed an interesting paper by Ove Paulsen on the Biology of *Calanus finmarchicus* in the waters round Iceland (Medd. Komm. Havundersog.—Plankton I., 1906), in which he comes to the conclusion that the shoals of herring around Iceland and also the Northern cod fishery depend mainly upon the distribution of *Calanus*. On account of the difference of his results under varying conditions of catching, he states that he has "discarded quantitative measurements or countings of the material," and yet he has given a very valuable paper, which shows, amongst other points, such a marked irregularity in the distribution of the young and old *Calanus* that I fail to see how anyone could deduce any definite conclusions as to the numbers of that organism in the sea.

In addition to the actual or relative numbers of different organisms in the sea, there are many other points that require consideration in connection with what some people call the "metabolism" of the ocean, and one of these points is the name metabolism. It is derived, of course, from the Greek "metabolē" (= change), and we apply the term in biology to two such very different things as the metamorphosis of an insect, and the series of changes that take place in a living body intervening between, and connecting, the ingestion of raw food materials and the elimination of waste products.

The changes of materials in the sea have no kind of connection with the metamorphosis of an insect, but they are to a limited extent analogous to the physiological metabolism in the living body. Nitrogenous products, for example, enter the sea as food stuffs, and can be traced in various conditions through the bodies of various organisms until, it may be, they leave the sea in the form

of a fish that has been caught. But that is only one half of the story—the nitrogen need not leave the sea, but may go on its beneficent course through a perpetual series of recurring cycles, which render possible the life and growth of successive generations of organisms. Then, again, another great series of the changes in the sea which we wish to designate must be regarded as constantly circulating within the sea, from the body of an organism to a dead deposit, then, it may be, passing into solution, and once more—perhaps after intermediate stages—becoming part of a living body again. The carbonate of lime in Corals, Foraminifera and Shells, and the silica in Sponges, Radiolaria and Diatoms is an example of such a series of phenomena, and cyclical change or circulation of matter is the English term which best expresses the facts of the case. If we must have a technical term in classical form I would propose "hylokinesis"* as being more comprehensive and appropriate than metabolism.

It seems possible to obtain a good deal of interesting information in regard to the hylokinesis of the sea without attempting a numerical accuracy which is not yet attainable. The details of measurement and computation become useless, and the exact figures are non-significant, if the hauls upon which they are based are not really comparable with one another and the samples obtained are not adequately representative of nature.

I wish now in a third, and concluding, section of this address to bring before you a problem in geographical distribution in which I have lately been much interested. In bringing to a conclusion my Report upon the Ceylon Pearl Fisheries I had to summarise the faunistic relations of the Gulf of Manaar, and it naturally occurred

* Kindly suggested to me by my colleague Prof. H. A. Strong

to me to institute a comparison between the animals of Ceylon and those of the Maldive archipelago recently explored by Mr. Stanley Gardiner. Ceylon is geologically and zoologically a part of the continent of India, while the Maldives are usually supposed to be a group of Oceanic Coral Islands. A comparison between a shallow water Continental Coast fauna and that of a group of Oceanic Coral Islands only, on the average, some 400 miles apart, in the same latitudes and the same sea, but separated by deep water, ought to be instructive. In comparing the numbers of animals in the chief groups from the two regions there are marked differences, some of which seem susceptible of explanation. A group of Oceanic Coral Islands must clearly have been populated from some of the surrounding older continental coasts, and the nearest of these to the Maldives are Ceylon and the southern end of India, some three to five hundred miles distant. There are two dominant factors that naturally play an important part in determining which animals from the neighbouring continent will form part of the new population, viz.:—(1) the means of transport possessed by the animals either in the adult or the larval condition, and (2) whether or not the conditions existing on the island are sufficiently favourable to the migrating animal on its arrival either as an adult or a larva.

Looking at the lists which are given in my Ceylon Report (Vol. V., p. 436) we find that the total number of animals is much greater in the recorded Ceylon fauna than in that of the Maldives, but that in certain groups—the Medusæ, Actinozoa, Gephyrea, Cirripedia and Macrura—the Maldivian numbers are the greater; while in other groups—such as Hydroida, Alcyonaria, Echinodermata, Platyelmia, Copepoda, Amphipoda, Isopoda and Mollusca—the Ceylon list markedly predominates.

Oceanic or pelagic groups, as would be expected, and coastal animals of active habit, possessing the necessary means of transport in the adult condition, are well represented in the Maldive fauna. For example, Fishes, Medusæ and Chaetognatha are all fairly abundant. The Cirripedia also, some of which are almost cosmopolitan in their distribution on the high seas, are more numerous than in Ceylon. The Copepoda might be expected to bulk larger than they do. The pelagic and more active forms are, however, present, and the deficiency is in the bottom-living species, many of which are associated with Sponges, Tunicates and other fixed colonies which are probably much more abundant at Ceylon than in the Maldives. The high number in the case of Actinozoa is due to species of Madreporaria which are, of course, abundant in a coral archipelago, and the species of which were especially studied by Mr. Stanley Gardiner. In the case of Macrura, the 79 species include 76 Alpheidæ, and the species of *Alpheus*, being closely associated in habitat with corals, would naturally be obtained in abundance amongst the reefs.

Turning to the other groups of animals which are more abundant at Ceylon, we find that it is the fixed and the more or less sedentary, bottom-living forms that are poorly represented in the Maldivian fauna, *e.g.*, Hydroida, Alcyonaria, Echinodermata and Mollusca. I should expect this to apply also to Sponges, Polyzoa and Tunicata, but these Maldivian groups have not yet been reported on. Most of these groups are dependent for dispersal upon minute, feeble and short-lived embryos or larvae, to which 400 miles of open sea may be a formidable obstacle.

In marked contrast to some of these groups there is the case of the Brachyura, where the numbers in the two faunas (Maldives 184 and Ceylon 208) are not very

different. The probable explanation is that the larvae of the crabs are powerful, locomotory, comparatively long-lived animals, which are frequently taken in the tow-net in the open sea, and are therefore much better fitted to survive the journey from the continental coast.* The most feebly represented of Crustacean groups are the Amphipoda and Isopoda, and I would suggest that the explanation is to be found in the unsuitability of their young stages for distribution to oceanic islands. Those that do cross in safety are probably carried accidentally on larger objects. It may conceivably be easier for a shallow water species, which neither in the adult nor larval life is adapted to a prolonged pelagic existence, to spread in the course of ages from India to Australia along the stepping-stones of Malaysia than to cross the stretch of open sea from Ceylon to the Maldives.

It must be remembered, however, that Mr. Stanley Gardiner has suggested that the Maldive Coral Islands have grown up from a platform of continental rock—part of the ancient land connection which in the Secondary period is supposed to have crossed the Indian Ocean from Ceylon to Madagascar, and which in the early Tertiaries may have been reduced to a chain of large islands. If that view is correct the interesting question arises—Must we conclude that the considerable number of bottom-living animals that are now common to Ceylon and the Maldives have been carried across the 400 miles of deep sea either in the adult or the larval condition since the coral archipelago was formed, or is it possible that any of them have continued to live on the Maldive plateau since the time (say in the early Eocene period) when it was last connected with the continent of India? This is one of the Oceanographic problems in the

* See also, Stanley Gardiner, Annals and Mag. Nat. Hist., for Dec., 1904.

solution of which the Zoologist and the Geologist join hands—and fortunately we have both in this Biological Society. It is a matter, moreover, upon which we are likely soon to have further information, as Mr. Stanley Gardiner has recently returned from his great exploring expedition from Ceylon down to the Seychelles, under the auspices of the Percy-Sladen Trust, and will doubtless in his forthcoming Reports, to be published by the Linnean Society, throw a flood of welcome light upon the present condition and past history of the bed of the Indian Ocean.

In this address I have endeavoured to lay before the Society two examples of modern problems of the sea which are, I think, eminently discussable; which will, I am sure, have to be still further discussed in the immediate future; and which, as they deal with wide general questions of nature, I hoped might prove of interest to all sections of naturalists in this Society.

THE MARINE BIOLOGICAL STATION AT PORT ERIN,

BEING THE

TWENTIETH ANNUAL REPORT

OF THE

LIVERPOOL MARINE BIOLOGY COMMITTEE.

As I have been able to devote a good deal of time to the affairs of the Biological Station this year, I now revert to the former plan of the Report in which Mr. Chadwick's contribution appears under the heading "Curator's Report"; but I am, as usual, indebted to him, or to his weekly reports for much of the information given under "The Station Record" and "The Aquarium."

Workers at our Biological Station have frequently had occasion in the past to deplore the absence of a small dredging steamer from the equipment for research at Port Erin. As I proposed to spend the greater part of the summer vacation in work at the Station this year, it seemed a favourable opportunity to test the advantages of having a boat suitable for dredging outside the bay. The steam-yacht "Madge" was chartered privately for two months, and was kept very fully employed during most of the time. I think it may be said that the experiment was a thorough success, not only from the point of view of my own special work, but also as an advantage to all others working at the Station. My main object in the work from the steamer was to test the catching power of various surface and deep-water silk nets with the view of estimating the value of the "samples" of the microscopic life of the sea obtained by such means, and I shall reprint as an appendix to this Report a paper giving the details of our observations which I had occasion

to draw up lately for the Biological Society. (See p. 1). But in addition to this special work a good deal of general collecting was carried on for the benefit of the Biological Station. The advantage of having a handy little steamer available for trawling, dredging, or tow-netting around Port Erin is now undoubted, and it is unfortunate that the finances of the Station do not permit of the L.M.B.C. having such a boat employed permanently.

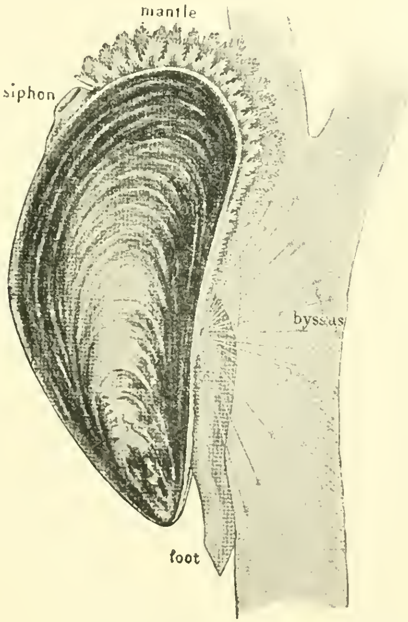


FIG. I.—*Mytilus edulis*, from Aquarium Guide.

The continued success of the Aquarium, and the marked increase in the number of visitors, is most gratifying. An institution where over fifteen thousand summer visitors are shown a number of the most interesting of our common sea-side animals and plants in a living condition amidst natural surroundings, with

labels, pictures and other information, must, surely, be doing something to encourage nature-study and to foster an appreciation of biology. About a thousand copies of the new edition of the "Guide to the Aquarium," which was drawn up and issued with the last Annual Report, have been sold at 3d. during the present summer. This enlarged edition of the "Guide" is a booklet of about 80 pages and over 40 illustrations. Copies, at 3d. each (post free 4½d.), can always be obtained by writing to Mr. Chadwick, at Port Erin.

The Station Record.

About twenty naturalists and students have occupied our Laboratories for periods of from one to eight weeks each during the year, as follows:—

Date.	Name.	Work.
Dec. 26th, 1905, to Jan. 5th, 1906	Mr. T. Southwell, A.R.C.S.	Histology of Calcareous Sponges.
Dec. 29th, 1905, to Jan. 9th, 1906	Prof. Herdman	Formation of Pearls.
January 31st to February 6th	Mr. Nils Hagman	Gases of Air-bladder of Fishes.
March 27th to April 11th	Mr. J. Pearson, M.Sc.	Blood system of Cancer pagurus.
March 30th to April 19th	Miss A. Isgrove	General.
March 30th to April 19th	Miss M. Kershaw	Marine Algæ.
April 2nd to April 19th	Mr. W. J. Dakin, B.Sc.	Embryology of Plaice and physiology of Pecten.
April 5th to April 19th	Mr. W. Gunn	Genera
April 7th to April 27th	Prof. Herdman	Tunicata.

DATE.	NAME.	WORK.
April 7th to April 23rd	Dr. H. E. Roaf	Digestion of Invertebrata.
April 12th to April 23rd	Miss W. Herdman	General.
April 17th to April 21st	Miss Hartley	General.
April 17th to April 21st	Miss Quinlan	General.
April 17th to April 21st	Miss Jeffreys	General.
April 18th to April 24th	Miss Shatwell	General.
April 24th to May 4th	Rev. T. S. Lea Rev. A. F. Mitchell	Photography of Marine animals.
June 1st to June 5th	Prof. Herdman	Official.
June 6th to June 11th	Mr. Arnold T. Watson, F.L.S.	Regeneration in Polychæte Worms.
July 21st to Sept. 17th	Prof. Herdman	Tunicata.
July 30th to August 11th	Mr. W. J. Dakin, B.Sc	Anatomy of Pecten.
August 28th to Sept. 11th	Mr. W. Gunn	General.
Sept. 20th to Oct. 9th	Dr. J. H. O'Connell	Actiniaria.

The "Tables" in the laboratory were occupied as follows:—

Liverpool University Table :—

Professor Herdman.
Mr. J. Pearson, M.Sc.
Mr. W. J. Dakin, B.Sc.
Dr. Roaf.
Mr. W. Gunn.
Miss W. Herdman.
Miss Hartley.
Miss Quinlan.
Miss Jeffreys.
Miss Shatwell.

Liverpool Marine Biology Committee Table :—

Mr. T. Southwell, A.R.C.S.	Rev. T. S. Lea.
Mr. Nils Hagman.	Rev. A. F. Mitchell.
Mr. Arnold T. Watson, F.L.S.	Dr. J. H. O'Connell.

Manchester University Table :—

Miss A. Isgrove.	Miss M. Kershaw.

Isle of Man Natural History Society Table :—

Mr. P. M. C. Kermode.	Mr. Wilkins.

In addition, Mr. Robert Okell, F.L.S., Secretary to the Manx Fishery Board, paid frequent official visits to the Biological Station.

Curator's Report.

I take the following paragraphs almost verbatim from the detailed report furnished to me by Mr. H. C. Chadwick:—

In addition to a good deal of general work done by the undergraduates of the Universities of Liverpool and Manchester, several important lines of original research were pursued by other more advanced workers. During the Christmas vacation Mr. Southwell, then of the Royal College of Science, carried on some research on the histology of the Calcareous Sponges. He was followed at the end of January by Mr. Nils Hagman, of the University of Helsingfors, who resumed some researches on the gases of the air-bladder of Fishes upon which he had previously been engaged at Bergen. Next in point of time came Mr. Pearson, who devoted a fortnight to the study of the blood system of the edible crab. Later, in the Easter vacation, Mr. Dakin devoted himself to the embryology of the plaice, and some preliminary work on the anatomy and physiology of *Pecten maximus*, while Dr. Roaf conducted some research on the digestive ferments of some typical marine animals. By no means the least interesting of the year's researches

was that conducted in June by Mr. Arnold Watson on regeneration in Polychæte worms, a line of research which will probably lead to results of considerable interest.

The library has been enriched during the year by donations of books from Mr. Robert Okell, F.L.S., and Mr. Frank Crisp, F.L.S., as well as by the purchase of

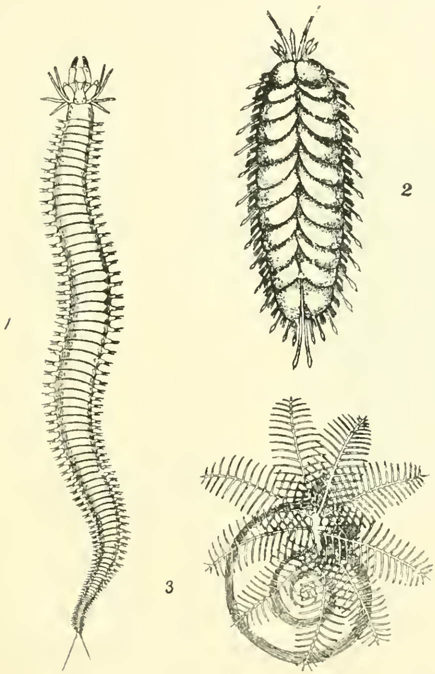


FIG. II.—Some Polychaete Worms.

several newly published volumes. There is, however, plenty of room on the shelves for a number of important works, the presentation of which would lay under obligation the present as well as succeeding generations of students.

A good deal of faunistic work has been done by students, and a considerable proportion of the Curator's time has been devoted to the collection and preservation of material for class and research purposes, amongst which may be specially mentioned several large series of embryos of *Doris tuberculata* for Sir C. Eliot. Two of these were preserved from ribbons of spawn deposited in one of the Aquarium tanks, so that it was possible to accurately determine the age of the embryos from day to day.

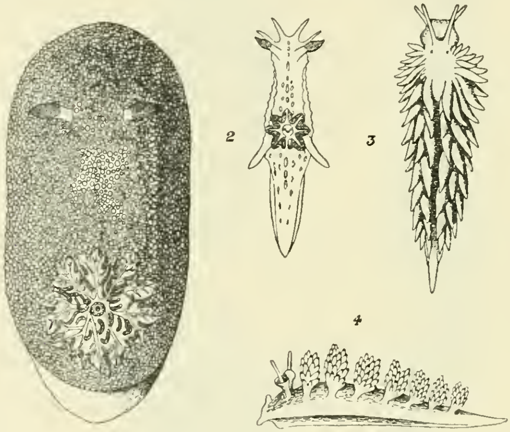


FIG. III.—*Doris tuberculata* and other Nudibranchs.

The additions made to the list of species recorded from the Irish Sea include the Gymnoblastic Hydroid found growing upon the carapace of the spiny lobster, *Palinurus vulgaris,* and upon the walls of the Aquarium tank in which it lived; the Actiniarian *Edwardsia carnea,* a number of which were found upon a much worn fragment of limestone which became entangled upon a fisherman's long line and was so hauled up from the sea-bottom; and the Gephyrean worm *Sipunculus bernhardus* of Forbes, several specimens of which were found

inhabiting some dead shells of *Dentalium* dredged by Professor Herdman. Miss A. Isgrove found a single specimen of another Gephyrean, *Phascolosoma vulgare*, which had not previously been recorded from Port Erin Bay. Mr. Dakin added *Gobius paganellus* to our list of Fishes.

Several large parties of girls and boys from the local elementary schools have paid visits to the Station under the guidance of their teachers, and were addressed on each occasion by the Curator.

On April 18th a lecture on the Pearl Fisheries and Ancient Temples of Ceylon was given by Professor Herdman, and was much appreciated by a good audience of local residents. The lecture was repeated on the 20th for the benefit of the local fishermen, who also attended in large numbers.

The Aquarium.

Over 15,000 visitors paid for admission to the Aquarium during the year. This number represents an increase of about 1,700 upon last year's total, and raises the total number of visitors admitted during the past four years to over 50,000. The largest attendance on one day was on August 16th, when 643 persons were admitted. The interest of the visitors has been greatly enhanced by the new edition of the Guide to the Aquarium, of which over 900 copies have been sold, making with the last 100 of the first edition, a total of over 1,000. This number represents a substantial increase upon the sales of any previous year, but it does not indicate the extent to which the Guide has been used, for we had evidence almost every day that copies had been lent by visitors to their friends, and that a preliminary perusal of their pages had stimulated the interest of many who had not before visited the Aquarium.

Amongst the many marine animals exhibited in the tanks the Octopus of the Irish Sea, *Eledone cirrosa* (see fig. 4), has maintained an easy first place in the estimation of the visitors. We were fortunate enough to obtain a good supply of this Cephalopod in the early spring, and the tank in which they lived always had its semi-circle of interested visitors.

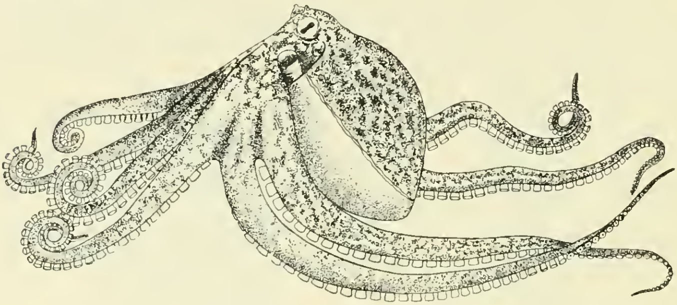


FIG. IV.—Our local "Octopus."

Next in point of interest came a number of young plaice, hatched on April 25th, and exhibited in a large dish alongside the series of table tanks. An explanatory label, bearing a sketch of the larva at the time of hatching, was appended, and led to the diffusion of a large amount of information upon the rate of growth and habits of this important food fish amongst many hundreds of visitors. I found a widely prevalent impression that the rate of growth of fishes is much more rapid than it really is, and many people expressed great astonishment on being told that a plaice takes at least two to three years to attain a size fit for the table.

The Aquarium tanks have been maintained in good condition throughout the year, and few of the specimens exhibited therein have died from what may, perhaps, be called natural causes.

The majority of our losses have been the result of

suspension of the circulation in one or more tanks owing to the growth, in the supply pipes, of living organisms, notably the tube-building Polychæte worm *Sabella pavonia* and the compound Tunicate *Botryllus smaragdus.* A large specimen of the former, inhabiting a tube nine inches long, was found obstructing the flow on one occasion, and a colony of the latter was in the same way responsible for the death of half-a-dozen sea bream. It is worthy of note that the colour in the case of both these organisms was not affected by the absolute darkness in which they had lived for so long a time. I examined both closely, and was not able to appreciate any difference between them and others of the same species living in the light.

Amongst the organisms which have appeared spontaneously in the tanks is a colony of the Monaxonid sponge *Halichondria panicea,* which has gradually attained large dimensions since I first noticed it quite early in the year. It is gradually extending itself over the back wall of the tank, and now measures about 16 inches by 8 inches. In addition to the Hydroid first noticed on the carapace of the spiny lobsters living in the tanks, and which is now being described by Miss Thornely, we have had extensive colonies of another species, *Podocoryne carnea,* living upon the gravel at the bottom of several of the tanks, and we were able to watch the liberation of the medusæ. Multitudes of another medusa, identified by Mr. E. T. Browne as probably young *Sarsia tubulosa,* were seen in several of the tanks, as well as in the spawning pond in the spring and early summer, and I am inclined to think that the parent Hydroid, a species of *Syncoryne,* is growing in quantity in the suction pipe through which the supply of water from the sea is drawn.

In last year's Report I recorded an extraordinary illustration of the voracity of the anemone *Tealia crassicornis.* I now have to record another, which, from a Curatorial point of view, was most exasperating. One of the additions to the list of the fauna of the Irish Sea recorded last year was the somewhat rare anemone *Aureliana augusta*, of which our single specimen lived in vigorous health until April 5th, when it was found to have disappeared from the spot occupied for some months previously. On the attention of the Assistant Curator being called to the sudden disappearance he at once suspected a large *Tealia* which adhered to a loose stone a few inches from the spot so recently occupied by the *Aureliana*, and, inserting his forefinger into its mouth, drew out the half-digested remains of the missing rarity.

Many years ago, when collecting on the beach at Beaumaris, I was fortunate enough on two occasions to see the Nemertine worm *Lineus marinus* attack and devour *Sabella pavonia* in its tube. Forgetful of this after the lapse of time, I placed a few specimens of that most beautiful of Serpulids, *Serpula vermicularis*, dredged by Professor Herdman, in one of our table tanks in which a *Lineus* had been lurking under the stones and broken shells for many months. A day or two later the Nemertine was found, true to its habit, dragging one of the helpless Serpulids from its tube, the large operculum not being sufficient to bar the entrance of the intruder. A specimen of *Lineus marinus* found under a stone on the beach in April measured 31 feet in length. The Polyzoon *Pedicellina cernua* has flourished in colonies of large extent on the side walls of three of our tanks throughout the year.

The friendly assistance of several fishermen enabled us, in the early spring, to re-introduce to our collection

of fishes two species which we had not previously succeeded in keeping more than a short time. These were the Lump-sucker (*Cyclopterus lumpus*) and the three-bearded Rockling (*Motella tricirrata*). Two young specimens of the former, caught in a herring-net some distance from land, were brought in, and one is still thriving in company with a number of Wrasses. The Rocklings have afforded us many opportunities of observing their extraordinary voracity in pursuit of food. During the day-time, at least, it is their habit to lie

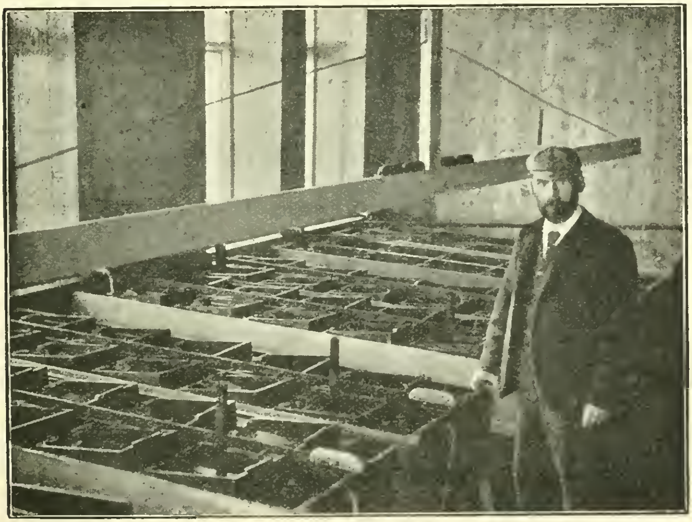


Fig. V.—The Fish Hatchery.

concealed amongst the large stones at the back of their tank, but the moment food, especially herring, is thrown into the water they leave their hiding places and boldly and successfully compete for it with fishes of larger size, such as the Pollack-whiting. We have frequently noticed that when in search of food on the bottom of the tank the

fish frequently touches the gravel with the tip of the single barbel borne by the lower jaw in much the same way as a dog will follow a trail of scent.

Passing now to the work of the fish hatchery, I may say that nearly five and a half millions of plaice fry were hatched from March 14th to May 18th inclusive. Of this number nearly four millions were liberated in the open sea, about half the remainder being transferred from our hatching boxes to the marine lake on the Mooragh at Ramsey, and the other half to the western portion of our spawning pond, which had been cleansed and reserved for their reception.

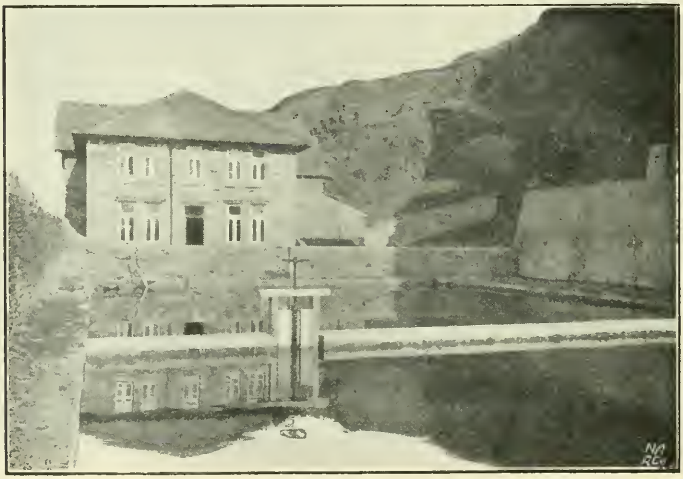


Fig. VI.—The Spawning Ponds.

We have, as yet, no information as to the result of the first of these experiments; that of the second is curious and, in one respect, quite unexpected, for, in spite of abundance of pure water and food, there has been considerable mortality amongst the fry, and a remarkable variation in their size when examined and measured on

October 3rd 162 days after they were hatched. Twelve taken at random varied in length from $1\frac{1}{8}$ inch to $2\frac{7}{8}$ inches, the average length being $1\frac{3}{4}$ inch. The same number taken from the eastern portion of the pond, the exact age of which is not known, showed much greater uniformity in size, and their average length was $3\frac{1}{2}$ inches. These young fish had apparently thriven better in association with about 250 adults than those in the other portion of the pond, where there were no organisms of larger size to compete with them for the great swarms of Copepoda and other organisms upon which they were seen to feed.

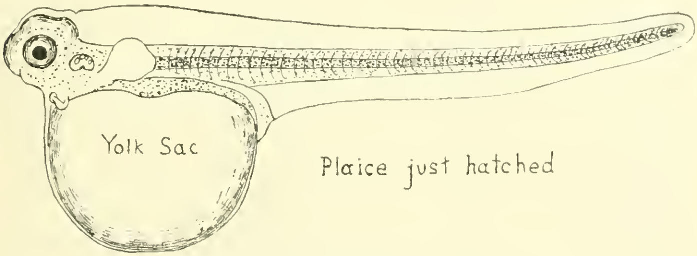


FIG. VII.—Larval Plaice. × 15.

The first fertilized eggs were seen in the pond on February 13th, and a small number were placed in one of the hatching boxes two days later. Thenceforward the numbers increased almost daily until April 2nd, when the maximum number of 511,000 was obtained. The last fertilized eggs were collected on May 1st, bringing the total to 6,072,600, and the total number of larvæ hatched during the season was 5,431,500. This was an increase of 335,000 compared with the total of the season of 1905; but, inasmuch as the number of spawners was smaller than that of the previous year (275 against 319 in 1905), the figures given do not indicate the full

measure of our success. The loss in working, this year, has been very small—a little over half-a-million in over six million eggs, being about 10·5 per cent.

The numbers of eggs collected and of larvæ set free during the season were as follows:—

Eggs collected.	Date.	Larvæ set free.	Date.	
7,200 ...	Feb. 20	... 5,000 ...	Mar. 14	
24,000 ...	„ 21	... 20,000 ...	„ 14	
16,000 ...	„ 22	... 12,500 ...	„ 14	
53,000 ...	„ 24	... 30,000 ...	„ 19	
49,000 ...	„ 26	... 41,000 ...	„ 19	
63,000 ...	„ 27	... 58,000 ...	„ 19	
63,000 ...	Mar. 1	... 58,000 ...	„ 22	
177,000 ...	„ 3	... 160,000 ...	„ 22	
334,000 ...	„ 5 & 7	... 315,000 ...	„ 26	
124,000 ...	„ 7 & 8	... 114,000 ...	„ 29	
201,600 ...	„ 10	... 187,000 ...	„ 31	
137,500 ...	„ 12 & 13	... 131,500 ...	Apr. 3	
277,500 ...	„ 14, 15, & 16	... 240,500 ...	„ 5	
104,000 ...	„ 17	... 97,000 ...	„ 7	
272,000 ...	„ 19 & 20	... 245,000 ...	„ 9	
155,000 ...	„ 21	... 144,000 ...	„ 11	
207,000 ...	„ 23	... 194,000 ...	„ 12	
245,000 ...	„ 27	... 228,000 ...	„ 14	
306,000 ...	„ 29	... 280,000 ...	„ 17	
448,000 ...	„ 29 & 30	... 413,000 ...	„ 18	
511,000 ...	Apr. 2	... 470,000 ...	„ 20	
291,000 ...	„ 4	... 275,000 ...	„ 24	
261,000 ...	„ 6	... 235,000 ...	„ 24	Part to Ramsey.
313,000 ...	„ 7	... 275,000 ...	„ 26	Into Pond.
340,000 ...	„ 9	... 310,000 ...	„ 30	
144,000 ...	„ 11	... 124,000 ...	„ 30	
153,000 ...	„ 12	... 130,000 ...	May 1	
396,000 ...	„ 14	... 310,000 ...	„ 5	
326,800 ...	„ 16, 17, & 19	... 276,000 ...	„ 7	
68,000 ...	„ 26	... 50,000 ...	„ 12	
5,000 ...	„ 28 & May 1	... 3,000 ...	„ 18	
6,072,600		5,431,500		
5,431,500				
641,100	Loss of a little over half a million.			

Further Faunistic Notes.

Mr. Andrew Scott, A.L.S., of the Lancashire Marine Laboratory at Piel, in the Barrow Channel, has sent me his usual report upon additions to our knowledge of the fauna of the district, as follows:

A short account of the swimming habit of the common lug-worm was given in the last annual Report. Further evidence in support of Mr. Chadwick's observation was obtained at Piel in the spring of the present year. On several occasions Mr. Johnstone and I saw as many as a dozen of these worms swimming about in one of the fish tanks. Some experiments were then made to find out if the habit was an accidental one, or due to unusual conditions. Freshly dug worms were tried, but they made no attempt to swim when thrown in, or even after the lapse of several minutes. Others that had been left in a shallow tank for a day or two, where there was no sand on the bottom, were next used. These gave the best results. When first thrown in, the worms gradually dropped to the bottom of the tank. On reaching the bottom a number at once commenced to swim in the manner described by Mr. Chadwick, and soon reached the surface, where they remained for a short period. They eventually returned to the bottom and a few repeated the movements again. After a time the worms, either due to exhaustion or having become more accustomed to the new conditions of pressure, abandoned their swimming and became quiescent. I have sometimes seen large *Nereis* swimming about in the shallow water during low tides in Barrow Channel, but this is the first time I have witnessed *Arenicola* swim.

The following additions have been made to the fauna of the Irish Sea since the last Annual Report:—

Leptocephalus morrisii, a perfect specimen of the tape-worm form of the "Leptocephalus" stage of the conger eel, was found by a local fisherman. The fish was discovered in a small pool between tide marks on the East side of Foulney Island, near Barrow. It was alive when captured, but as the man had no means of keeping it alive he brought it to me dead. The fish was like a strip of softened gelatine, and so thin and transparent that it was possible to read ordinary print through it.

The eggs of mackerel, long rough dab and variegated sole have been taken in various tow-nettings during the year. They have never previously been detected in the area, although the adult fish are not uncommon. The eggs of the anchovy were found in tow-nettings from Aberdovey in June and July. Ten years ago, the late R. L. Ascroft found them off Lytham, which was the first record of their occurrence in British seas.

Eurydice spinigera, H. J. Hansen, five specimens of this isopod were taken in a surface tow-netting in Red Wharf Bay on September 7th, and one near New Quay Head on October 7th, 1906.

Eurydice inermis, H. J. Hansen, one specimen was captured by the surface tow-net during the cruise of the s.y. "Madge," two miles West of Bradda Head, on September 8th.

Dajus mysidis, Kroyer, one female of this parasitic isopod was found in the incubatory pouch of a *Mysis ornatus* taken in a bottom tow-netting, in the vicinity of the Liverpool North-West Light Ship on January 31st, 1906. A large number of *Mysis* were captured, but only one had a parasite.

Asterope mariæ (Baird), one specimen of this ostracod was found in a surface tow-netting taken late at night in Port Erin Bay on September 26th, 1906.

Caligus zei, Norman and T. Scott, several specimens of this copepod parasite were found attached to the skin of a "John Dory" taken in the trawl of the "John Fell" while fishing off New Quay Head, on June 16th, 1906. The only other known specimens of this parasite were taken forty years ago.

Lernæenicus encrasicoli (Turton), another copepod parasite. A large catch of sprats were taken off Blackpool by the "John Fell" on February 19th, 1906, and part of it was landed at Piel. On going over the fish carefully, one sprat with two parasites attached, and another with one, were found. The parasites were embedded in the tissues at the anterior end of the dorsal fin. On dissecting one out, it was found that the head had penetrated to the visceral cavity.

Sphæronella paradoxa, H. J. Hansen, one specimen of this curious little parasite, belonging to the Choniostomatidae, was found in the incubatory pouch of the amphipod *Bathyporeia pelagica*, taken in a bottom tow-netting near Conway, on February 5th, 1906. Representatives of the family are not uncommon on the East coast of Scotland, but this is the first member taken in the Irish Sea.

Bio-Chemical Work.

During the Easter vacation Dr. H. E. Roaf continued his experimental work commenced with Professor Moore the previous year. His object was to study the bio-chemistry of the digestive processes in higher invertebrata, and the animals made use of were *Cancer pagurus*, *Carcinus moenas*, *Patella vulgata*, *Fusus antiquus*, *Purpura lapillus* and *Littorina littorea*. In all these Crustacea and Molluscs proteolytic, amylolytic and inverting ferments were found, as well as a ferment which hydrolysed methyl

acetate but had no appreciable action on olive oil. In the Crustacea it was found that the proteolytic action was more marked in an alkaline medium; while in the Mollusca it only took place in an acid reaction. In addition, a preliminary chemical examination of the glands was made. The results are published in the "Bio-Chemical Journal" (Vol. I., p. 390, 1906).

L.M.B.C. Memoirs.

After an interval of rest, a period of activity is now beginning again in the production of Memoirs. The last Memoir recorded in these Reports was No. XII,

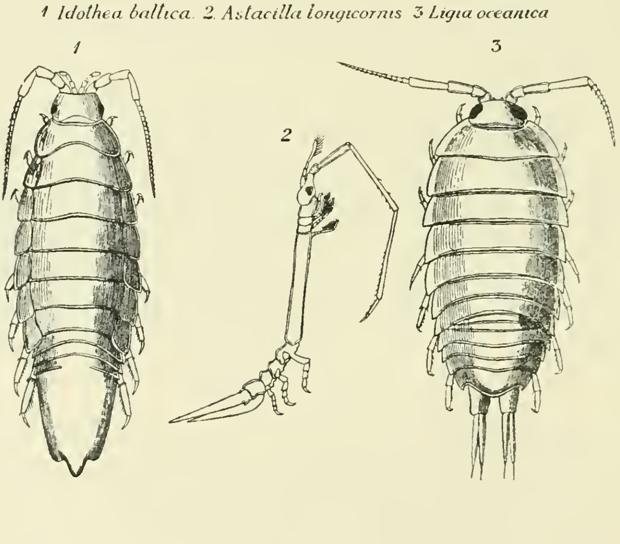


Fig. VIII.—*Ligia*, and other Isopods.

"Gammarus," by Miss Cussans, issued in 1904. No. XIII., "Anurida," the very primitive and interesting marine insect, by Mr. A. D. Imms, was published this autumn; No. XIV., "Ligia," the large shore Isopod, by

Mr. C. Gordon Hewitt, is now all in type, and will probably be out before the end of the year; "Antedon," the rosy feather-star, by Mr. Chadwick, is nearly completed; "Cancer," the edible crab, by Mr. Pearson; "Pecten," the scallop, by Mr. Dakin; and "Doris," the sea-lemon, by Sir Charles Eliot, are all far advanced. This unusual amount of excellent material, which the Committee is happy to be able to issue to the scientific

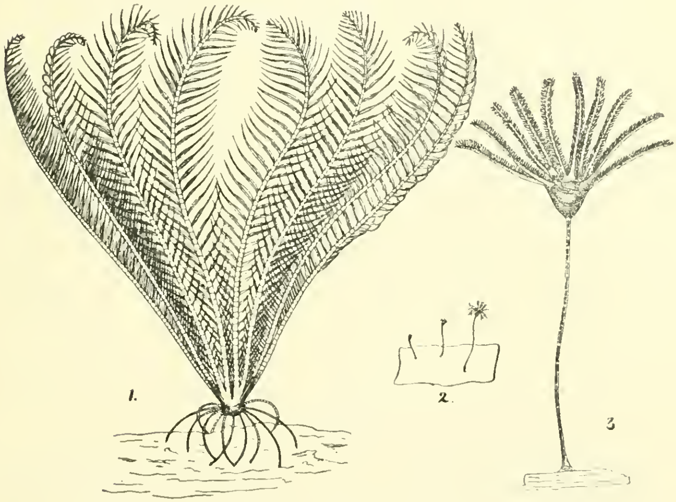


FIG. IX.—The Rosy Feather-star—Adult and young.

world, is, however, embarrassing from the point of view of expense. Lithographic plates, such as these Memoirs require, seem to become more costly, and with the growing elaboration of the subject more detailed illustration is necessary. The Committee are therefore very grateful to Sir John Brunner for a welcome donation of £50 which he has kindly sent to the Treasurer, to meet the expenses of plates for several of the above-mentioned Memoirs.

The following shows a list of the Memoirs already published or arranged for:—

Memoir I. Ascidia, W. A. Herdman, 60 pp., 5 Pls., 2s.
,, II. Cardium, J. Johnstone, 92 pp., 7 Pls., 2s. 6d.
,, III. Echinus, H. C. Chadwick, 36 pp., 5 Pls., 2s.
,, IV. Codium, R. J. H. Gibson and Helen Auld, 26 pp., 3 Pls., 1s. 6d.
,, V. Alcyonium, S. J. Hickson, 30 pp., 3 Pls., 1s. 6d.
,, VI. Lepeophtheirus and Lernæa, Andrew Scott, 62 pp., 5 Pls., 2s.
,, VII. Lineus, R. C. Punnett, 40 pp., 4 Pls., 2s.
,, VIII. Plaice, F. J. Cole and J. Johnstone, 260 pp., 11 Pls., 7s.
,, IX. Chondrus, O. V. Darbishire, 50 pp., 7 Pls., 2s. 6d.
,, X. Patella, J. R. A. Davis and H. J. Fleure, 84 pp., 4 Pls., 2s. 6d.
,, XI. Arenicola, J. H. Ashworth, 126 pp., 8 Pls., 4s. 6d.
,, XII. Gammarus, M. Cussans, 55 pp., 4 Pls., 2s.
,, XIII. Anurida, A. D. Imms, 107 pp., 8 Pls., 4s. 6d.
,, XIV. Ligia, C. G. Hewitt.
Antedon, H. C. Chadwick.
Cycloporus, F. F. Laidlaw.
Cancer, J. Pearson.
Pecten, W. J. Dakin.
Oyster, W. A. Herdman and J. T. Jenkins.
Ostracod (Cythere), Andrew Scott.
Doris, Sir Charles Eliot.
Buccinum, W. B. Randles.
Bugula, Laura R. Thornely.
Zostera, R. J. Harvey Gibson.
Himanthalia, F. J. Lewis.
Fucus, J. B. Farmer.

BOTRYLLOIDES, W. A. Herdman.
CUTTLE-FISH (ELEDONE), W. E. Hoyle.
ACTINIA, J. A. Clubb.
HALICHONDRIA and SYCON, A. Dendy.
HYDROID, E. T. Browne.

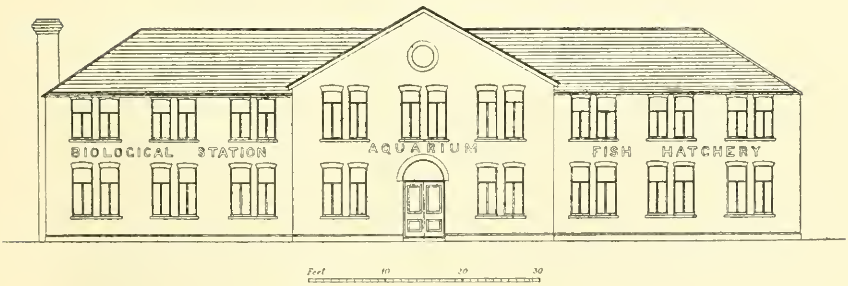
In addition to these, other Memoirs will be arranged for, on suitable types, such as *Sagitta*, *Pontobdella*, a Cestode and a Pycnogonid.

We append to this Report:—

(A) Mr. Andrew Scott's Notes on the results of these same investigations;

(B) The usual Statement as to the constitution of the L.M.B.C., and the Laboratory Regulations;

(C) The Hon. Treasurer's Report, List of Subscribers, and Balance Sheet.



Front Elevation of Biological Station.

Appendix A.

Notes on Special Plankton Investigations.

By Andrew Scott, A.L.S.

In addition to the tow-nettings from Port Erin Bay taken at intervals by Mr. Chadwick, an interesting series of special samples of the plankton was made by Professor Herdman from the s.y. "Madge," between July 22nd and September 17th. This series was collected by various kinds of nets simultaneously, at depths from zero to twenty fathoms, between Jurby Point and the Calf of Man, and was represented by 74 gatherings. It is only proposed to give a few of the more striking results here, as a detailed account will be presented later to the Biological Society. It might be mentioned, in passing, that the nets comprised ordinary tow-nets, old and new, worked side by side, a small Apstein net used at the surface, a Hensen-Petersen self-closing net towed at a depth of 5 to 7 fathoms and then closed before being drawn to the surface, and a weighted ordinary tow-net worked at a depth varying from 5 to 15 fathoms.

On measuring and examining the material, it was found that, although the gatherings were taken in equal periods of time, in a very limited sea-area, there was no uniformity either in quantity or kind of organisms captured. Some days the surface net contained a larger quantity of material than the deep one, and on other days there was more in the deep net than in the surface one. The old surface net which had been used many times previous to this special work appeared to fish better than the new one, which had not been used before. The Apstein net invariably captured fewer organisms than the ordinary net.

Working N. of the Calf Island, the surface net captured 5 c.c. of organisms on the 9th of August, 1 c.c. on the 10th, 8 c.c. on the 13th, and $3\frac{1}{2}$ c.c. on the 14th. The organisms represented on the 9th were *Ceratium tripos*, *Sagitta*, *Autolytus*, Zoea and Megalopa of crabs, "Mysis" stage of *Crangon*, *Oikopleura*, *Calanus*, *Pseudo-*

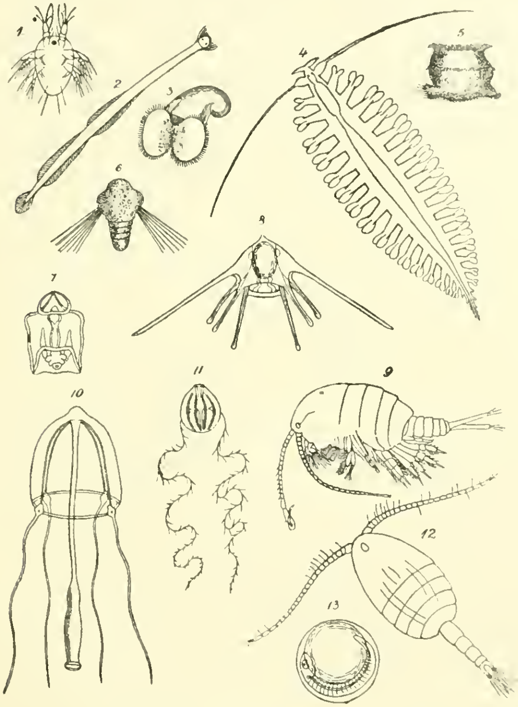


FIG. IX.—A general gathering of Plankton, or floating organisms caught in the tow-net ; 9 is *Temora*, and 12 *Pseudocalanus* (both × 10).

calanus, *Paracalanus*, *Acartia clausi*, *Anomalocera*, *Oithona similis*, Copepod nauplii, and fish (Rockling) eggs. On the 10th *Autolytus*, Zoea and Megalopa, *Anomalocera* *Oithona*, and fish eggs were absent, but Medusoid gonophores, *Centropages hamatus*, and *Temora* were

present. The collection taken on the 13th was similar to the one on the 10th, except that Medusoids were replaced by *Pleurobrachia*; *Pseudocalanus* was absent and the diatom *Chætoceros* was present. The gathering taken on the 14th resembled that of the 9th, with the exception that the Copepoda were reduced to two species (*Oithona* and *Acartia*) and three kinds of fish eggs in place of one. The constituents of the under-surface collections taken at the same place, on the above mentioned dates, differed in variety from each other, and also from the surface collections, besides differing to some extent in quantity.

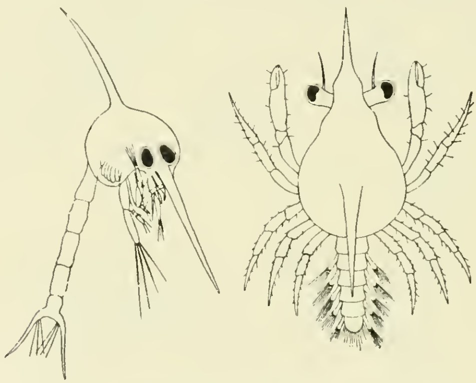


FIG. X.—Crab Zoea and Megalopa (enlarged).

On the 9th, the collection (5 to 7 fathoms) consisted of 1 c.c. of organisms, and contained *Chætoceros*, *Ceratium tripos*, Medusoid gonophores, *Sagitta*, *Tomopteris*, Crab Zoea, *Podon*, *Pseudocalanus*, *Temora*, *Isias*, *Acartia*, *Oithona*, Copepod nauplii, *Oikopleura*, and Rockling eggs. The organisms present at the surface but absent from the lower water were *Autolytus*, Crab Megalopa, "Mysis" stage of *Crangon*, *Calanus*, and *Anomalocera*. The collection taken on the 10th (5 to 7 fathoms) was the same in bulk as the surface one, and differed very little from it;

two organisms present at the surface (Medusoid gonophores and *Centropages*) were absent and their places were taken by *Autolytus* and Crab Megalopa. The deep water (10 fathoms), on the 13th, had apparently more abundant life than the surface of the same date. The quantity taken measured 32 c.c., and was rich in Copepoda. *Centropages* and *Oithona* were entirely absent from the deep collection; the latter was very abundant at the surface; *Pseudocalanus* was tolerably common at 10 fathoms but not represented at the surface; *Chætoceros*, *Ceratium tripos* and *C. furca*, *Pleurobrachia* and *Autolytus* were absent at 10 fathoms, but Crab Zoea, *Podon*, *Evadne*, and Rockling eggs were present. The quantity taken by the deep net on the 14th measured 40 c.c., and was again rich in Copepoda, the genera present being *Calanus*, *Pseudocalanus*, *Temora*, *Centropages*, and *Acartia*. *Oithona*, although very plentiful at the surface, was not represented in the deep collection. This is rather interesting; on two consecutive days *Oithona* appeared to be confined to the surface layer of the sea-water, while collections taken a week later in the same place showed that it was present all through the water, from surface to bottom. *Chætoceros*, *Ceratium*, Megalopa and fish eggs, which were noted at the surface, were absent from the deeper water, their places to some extent being taken by *Tomopteris*, Crab Zoea, and *Evadne*.

Collections taken off Niarbyl, on August 27th and 28th, showed variation in quantity and in constituents. The amount of plankton taken at the surface on the 27th was 11 c.c., and on the 28th 3 c.c. The contents of the deep net (10 to 15 fathoms) on the 27th measured 5 c.c., and at 10 fathoms, on the 28th, 2 c.c. The Hensen net, towed at 5 to 7 fathoms on the 27th, yielded $8\frac{1}{2}$ c.c. Four organisms (Megalopa, *Pseudocalanus*, *Anomalocera*, and

Parapontella), although present at the surface on the 27th, were absent on the following day. On the other hand, Crab Zoea, *Evadne*, and two kinds of fish eggs, noted on the 28th, were absent on the previous day. The deep gatherings differed from each other and also from the surface. On the 27th, *Biddulphia*, *Sagitta*, *Tomopteris*, Crab Zoea, and *Centropages*, were present in the deep net, but not at the surface. On the following day, when a smaller bulk of material was taken, *Biddulphia*, *Ceratium*, Medusoid gonophores, *Tomopteris*, and *Podon*, all present the day before, had disappeared. On the 28th, hauls taken a few miles to the North, off Jurby, differed greatly in quantity from those off Niarbyl, the surface net having 13 c.c. and that at 10 fathoms 9 c.

On September 11th and 12th the water close under the East side of the Calf Island was investigated by means of old and new surface nets, Apstein net, Hensen net, and weighted ordinary tow-net. On the first date the old surface net captured 8 c.c. and the new one 5 c.c. of organisms. On the following day the old net contained 1½ c.c. and the new one 2 c.c. of plankton. The Hensen net, worked at 5 to 7 fathoms, collected 2½ c.c. each day. The deep net, at 10 fathoms, took 15 c.c. on the 11th and only 6 c.c. on the 12th. The old and new nets working side by side on the 11th did not capture exactly the same kind of organisms. The old net contained *Autolytus*, Crab Zoea and Megalopa, and *Idotea*, not represented in the new net; on the other hand, the new net captured *Coscinodiscus*, *Biddulphia*, *Ceratium*, and *Pseudocalanus*, which were not taken in the old net. The organisms taken by these nets on the following day were almost identical, the only difference being *Calanus* present in the old net but not in the new one. Seven species of Copepoda were noted in the surface gathering on the 11th

September, and only four species in the deep collection. On the 12th, eight species of Copepoda were present at the surface and five species at 10 fathoms. Copepoda were the chief constituent in the majority of the collections taken during the cruises of the "Madge" up to September 17th, when this special work came to an end. A week later Professor Herdman returned to Port Erin for

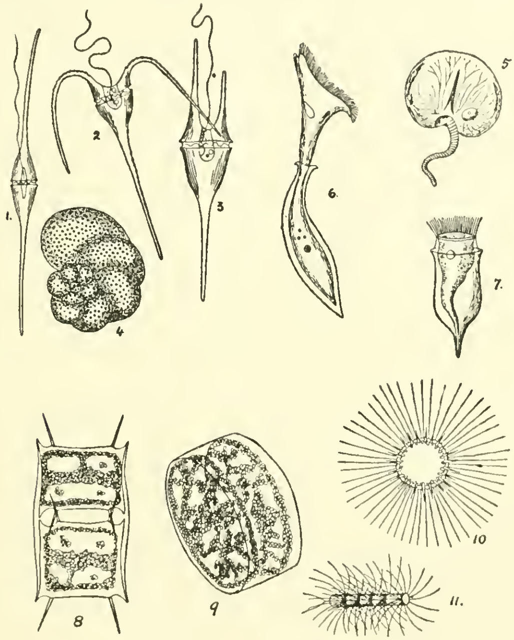


FIG. XI.—Protozoa and Diatoms (highly magnified).
1-3, *Ceratium;* 5, *Nootiluca;* 8-11, Diatoms.

a short visit, and during that time took six surface townettings from a rowing boat on three consecutive days—September 25th to 27th. Four of the collections were made in Port Erin Bay, one in Bay Fine, on the way to Calf Island, and one in the open sea off Bradda Head.

The amount of material collected varied from 16 c.c. to 28 c.c. Every haul was practically a gathering of diatoms (*Chætoceros*), with comparatively few Copepods and other organisms. Another week later (October 4th) Mr. Chadwick took a surface tow-netting in Port Erin Bay, which revealed another complete change in the plankton. The diatoms had almost entirely disappeared, and a large number of Copepods, chiefly *Pseudocalanus* and *Paracalanus*, were then present.

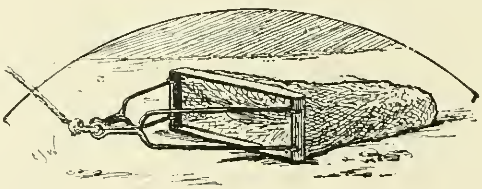
The distribution of the pelagic life in the sea is influenced by many circumstances—winds, currents, sunshine and shadows, light and darkness, temperature and salinity are important factors. These agencies at all times have great effect in increasing or diminishing the quantity and variety of organisms present. We know a very great deal more regarding the distribution of certain classes of pelagic and semi-pelagic organisms now than we did a few years ago. For example, many Copepoda which were at one time regarded as strictly limited to particular regions are now known to have a very wide range. Every scientific expedition throws fresh light on the subject. There are still quite a number of such organisms whose known distribution is very limited, but whether they will prove on further investigation to be so local is very doubtful. A collection of plankton taken by Dr. H. E. Roaf this summer during a traverse to Quebec and back, revealed some interesting facts regarding the distribution of certain Copepoda, &c. *Calanus* was represented in every gathering on the outward journey, but the collections from mid-Atlantic contained a much greater number of specimens than any of the others. On the homeward traverse *Calanus* was absent from one or two collections; again, however, the mid-ocean gatherings contained the greatest quantity.

Acartia clausi was tolerably frequent on the English side, but appeared to be entirely absent on the Canadian coast. This particular species was replaced there by another member of the genus, *A. longiremis*, which was very abundant in the St. Lawrence, but is rarely met with in the Irish Sea. *Metridia longa*, a cold-water Copepod, was fairly plentiful about the time the ship was passing through the area affected by the Arctic current. It was only taken during a period of forty-eight hours' steaming. Off the Irish coast *Metridia lucens* was noted. This species was recorded by I. C. Thompson and myself, in the Report on the Ceylon Copepoda, as extending from the English Channel to the Gulf of Suez. One and a half days after Dr. Roaf left Liverpool the ship apparently encountered a swarm of *Evadne nordmanni*, which was the chief constituent of the collection then taken. A few were noted in the gathering of the previous day, but after that no more were found till the ship had entered the Gulf of St. Lawrence.

Coming back to our own immediate neighbourhood, we find, from a recent expedition in the Lancashire Fisheries steamer, an interesting state of affairs. On November 13th, starting from Piel Gas Buoy and proceeding N.W. to the Isle of Man, four hauls were made with a Hensen quantitative net. The first haul was made six miles from the gas buoy, the second 15 miles, the third 24 miles, and the fourth 42 miles off the buoy. That is, each of the three last hauls was made nine miles away from the preceding one. The four hauls all contained an abundance of diatoms, representing several genera and species, but the quantity varied in each haul. The first haul contained 4 c.c., the second 1 c.c., the third 2 c.c., and the fourth $2\frac{1}{2}$ c.c. of material. In the first haul *Rhizosolenia semispina* and *Chætoceros* (3 or 4 species) were

the prevailing forms. In the second haul *Coscinodiscus concinnus* was the chief constituent. In the third haul an abundance of *Eucampia zodiacus* and a fair quantity of *Rhizosolenia* was found. The fourth haul was very similar to the first. Copepoda were comparatively scarce throughout the traverse and consisted mainly of *Paracalanus* and *Oithona*. The first haul contained one *Calanus* and six *Temora*. *Temora* was not taken again, and the second and third hauls had no *Calanus*. The fourth haul contained eight *Calanus*. Amongst other things, *Noctiluca* and *Sagitta* were tolerably common in the four hauls.

The cruise was continued to the West side of the Isle of Man. Six miles N. from Peel another haul was taken, which revealed a complete change in the plankton. The quantity measured ½ c.c., and in it were three *Sagitta* and sixteen *Calanus*. *Pseudocalanus*, *Acartia*, and *Oithona* were tolerably common. Four genera of diatoms, each represented by a very few specimens, a few larval Polychæta, *Ceratium tripos* and *C. fusus*, and "Mitraria," but no *Noctiluca*, were taken. A quantitative estimation of the plankton obtained during that particular cruise is of course possible; but to say that every cubic metre traversed contained a definite number, or even an average number of *Coscinodiscus*, *Rhizosolenia*, *Calanus* or *Temora* would be unjustifiable and misleading.



The Naturalist's Dredge.

Appendix B.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE (1906).

His Excellency the Right Hon. Lord Raglan, Lieut.-Governor of the Isle of Man.
Mr. R. D. Darbishire, B.A., F.G.S., Manchester.
Prof. R. J. Harvey Gibson, M.A., F.L.S., Liverpool.
Mr. W. J. Halls, Liverpool.
Prof. W. A. Herdman, D.Sc., F.R.S., P.L.S., Liverpool, Chairman of the L.M.B.C., and Hon. Director of the Biological Station.
Dr. W. E. Hoyle, M.A., University, Manchester.
Mr. P. M. C. Kermode, Ramsey, Isle of Man.
Mr. A. Leicester, Liverpool.
Sir Charles Petrie, Liverpool.
Mr. E. Thompson, Liverpool, Hon. Treasurer.
Mr. A. O. Walker, F.L.S., J.P., formerly of Chester.
Mr. Arnold T. Watson, F.L.S., Sheffield.

Curator of the Station—Mr. H. C. Chadwick.
Assistant—Mr. T. N. Cregeen.

CONSTITUTION OF THE L.M.B.C.

(Established March, 1885.)

I.—The Object of the L.M.B.C. is to investigate the Marine Fauna and Flora (and any related subjects such as submarine geology and the physical condition of the water) of Liverpool Bay and the neighbouring parts of the Irish Sea and, if practicable, to establish and maintain a Biological Station on some convenient part of the coast.

II.—The Committee shall consist of not more than 12 and not less than 10 members, of whom 3 shall form a quorum; and a meeting shall be called at least once a year for the purpose of arranging the Annual Report, passing the Treasurer's accounts, and transacting any other necessary business.

III.—During the year the Affairs of the Committee shall be conducted by an Hon. Director, who shall be Chairman of the Committee, and an Hon. Treasurer, both of whom shall be appointed at the Annual Meeting, and shall be eligible for re-election.

IV.—Any Vacancies on the Committee, caused by death or resignation, shall be filled by the election at the Annual Meeting, of those who, by their work on the Marine Biology of the district, or by their sympathy with science, seem best fitted to help in advancing the work of the Committee.

V.—The Expenses of the investigations, of the publication of results, and of the maintenance of the Biological Station shall be defrayed by the Committee, who, for this purpose, shall ask for subscriptions or donations from the public, and for grants from scientific funds.

VI.—The Biological Station shall be used primarily for the Exploring work of the Committee, and the Specimens collected shall, so far as is necessary, be placed in the first instance at the disposal of the members of the Committee and other specialists who are reporting upon groups of organisms; work places in the Biological Station may, however, be rented by the week, month, or year to students and others, and duplicate specimens which, in the opinion of the Committee, can be spared may be sold to museums and laboratories.

LIVERPOOL MARINE BIOLOGICAL STATION

AT

PORT ERIN.

Laboratory Regulations.

I.—This Biological Station is under the control of the Liverpool Marine Biological Committee, the executive of which consists of the Hon. Director (Prof. Herdman, F.R.S.) and the Hon. Treasurer (Mr. E. Thompson).

II.—In the absence of the Director, and of all other members of the Committee, the Station is under the temporary control of the Resident Curator (Mr. H. C. Chadwick), who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boats, collecting apparatus, &c., are to be employed.

III.—The Resident Curator will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, at fixed hours, to see the Aquarium and Museum adjoining the Station. Occasional public lectures are given in the Institution by members of the Committee.

V.—Those who are entitled to work in the Station, when there is room, and after formal application to the Director, are:—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for three weeks), and (2) others who are not annual subscribers, but who pay the Treasurer 10s. per week for the accommodation and privileges.

Institutions, such as Universities and Museums, may become subscribers in order that a work place may be at the disposal of their students or staff for a certain period annually; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

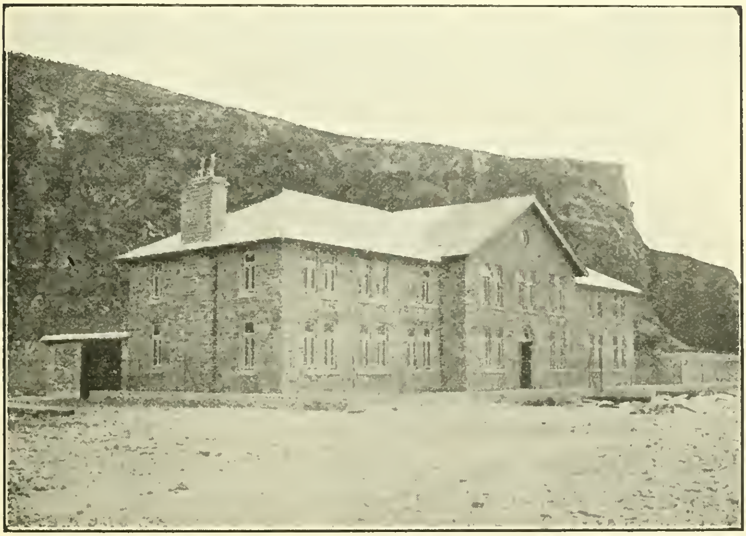
VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away collections of marine animals and plants, can make special arrangements with the Director or Treasurer in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Committee. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steam-boat dredging expeditions are defrayed by the Committee, the specimens obtained on these occasions must be retained by the Committee (*a*) for the use of the specialists working at

the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to lay a paper on some of his results—or at least a short report upon his work—before the Biological Society of Liverpool during the current or the following session.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer. Applications for permission to work at the Station, or for specimens, or any communications in regard to the scientific work should be made to Professor Herdman, F.R.S., University, Liverpool.



Port Erin Biological Station.

Appendix C.

HON. TREASURER'S STATEMENT.

The list of Subscribers and Balance Sheet for 1906 is shown in the few pages following. The latter shows a small balance due to the Treasurer.

The New Biological Station has been in full occupation for some years, and the working expenses are considerably greater than in the days of the less commodious building: also there is greater scope now for the Committee to open up further fields of useful work, and this is being done on a larger scale each year. There is, therefore, a greater necessity for increased support either by annual subscriptions or by special donations.

A welcome donation of fifty pounds has been received from Sir John Brunner to the special fund for publishing the Marine Biological Memoirs. Fourteen Memoirs with excellent plates have already been published; several new ones are ready for printing; and further contributions for this object will be gladly received, in order that there may be as little delay as possible in their publication.

There is a useful library at the Port Erin Biological Station for the use of students and other workers, but it is urgently in need of many standard Biological Works. Further donations towards the library, either in books or money, will be most welcome.

The Treasurer will gladly receive the names of new subscribers with the view of continuing the publications on the local Fauna and on typical British marine animals and plants, and of aiding to defray the necessary working expenses of the Biological Station at Port Erin.

Edwin Thompson,
Hon. Treasurer.

1, Croxteth Grove,
Liverpool, December, 1906.

SUBSCRIBERS.

	£	s.	d.
Beaumont, W. I., Citadel Hill, Plymouth ...	1	1	0
Bickersteth, Dr., 2, Rodney-street...	2	2	0
Briscoe, F. W., Colby, Isle of Man	1	1	0
Brown, Prof. J. Campbell, University, Liverpool..	1	1	0
Browne, Edward T., B.A., 141, Uxbridge-road, Shepherd's Bush, London	1	1	0
Boyce, Sir Rubert, F.R.S., University, Liverpool	1	1	0
Brunner, Mond & Co., Northwich...	1	1	0
Brunner, Sir J. T., Bart., M.P., Liverpool ...	5	0	0
Caton, Dr., 78, Rodney-street, Liverpool	1	1	0
Clubb, J. A., Public Museums, Liverpool... ...	0	10	6
Cowley, R. C., Laurel Bank, Garston	0	10	6
Crellin, John C., J.P., Andreas, I. of Man... ...	0	10	6
Crosfield, Harold G., Fulwood Park, Liverpool ...	1	1	0
Dale, Vice-Chancellor, University, Liverpool ...	1	0	0
Dixon-Nuttall, F. R., J.P., F.R.M.S., Prescot ...	2	2	0
Eliot, Sir Charles, University, Sheffield	1	1	0
Gair, H. W., Smithdown-rd., Wavertree ...	2	2	0
Gamble, Sir David, C.B., St. Helens	2	0	0
Gaskell, Holbrook, J.P., Woolton Wood	1	1	0
Gossage, Fred. H., Camp Hill, Woolton	5	0	0
Halls, W. J., 35, Lord-street, Liverpool	1	1	0
Headley, F. W., Haileybury College, Hertford ...	1	1	0
Herdman, Prof., F.R.S., University, Liverpool ...	2	2	0
Hewitt, David B., J.P., Northwich	1	1	0
Hickson, Prof., F.R.S., University, Manchester ...	1	1	0
Holland, Walter, Carnatic Hall, Mossley Hill ...	2	2	0
Holt, Alfred, Crofton, Aigburth	2	2	0
Holt, Alfred, Junr., Crofton, Aigburth	1	0	0
Forward	£42	17	6

	£	s.	d.
Forward	42	17	6
Holt, Mrs., Sudley, Mossley Hill	2	2	0
Holt, P. H., Croxteth-gate, Sefton-park	1	1	0
Holt, R. D., 54, Ullet-road, Liverpool	2	0	0
Hoyle, Dr. W. E., Museum, Owens College ...	1	1	0
Isle of Man Natural History Society	1	1	0
James, C. H., Holzendorff, Grange View, Leeds ...	1	1	0
Jarmay, Gustav, Hartford, Cheshire	1	1	0
Jones, Charles W., J.P., Allerton Beeches ...	1	0	0
Lea, Rev. T. Simcox, Leek Vicarage, Kirkby Lonsdale	1	1	0
Leicester, Alfred, 30, Brunswick-street, Liverpool	1	1	0
Lewis, Dr. W. B., W. Riding Asylum, Wakefield...	1	0	0
Manchester Microscopical Society...	1	1	0
Meade-King, R. R., 4, Oldhall-street	0	10	6
Monks, F. W., Warrington...	2	2	0
Muspratt, E. K., Seaforth Hall	5	0	0
O'Connell, Dr. J. H., Dunloe, Heathfield Road, Liverpool	1	1	0
Okell, R., B.A., F.L.S., Sutton, Douglas, I. of Man	1	1	0
Petrie, Sir Charles, Devonshire-road	1	1	0
Pilkington, J. A., Bank House, Maghull	0	10	0
Quayle, Alfred, 7, Scarisbrick New-road, Southport	1	1	0
Rae, Edward, Courthill, Birkenhead	1	1	0
Rathbone, Mrs. Theo., Backwood, Neston... ...	1	1	0
Rathbone, Miss May, Northumberland Street, London	1	1	0
Rathbone, Mrs., Green Bank, Allerton	2	2	0
Roberts, Mrs. Isaac, Thomery, S. et M., France ...	1	1	0
Robinson, Miss M. E., Holmfield, Aigburth, L'pool	1	0	0
Simpson, J. Hope, Aigburth-drive	0	10	6
Smith, A. T., 43, Castle-street	1	1	0
Sorby, Dr. H. C., F.R.S., Broomfield, Sheffield ...	1	1	0
Tate, Sir W. H., Woolton, Liverpool	2	2	0
Thompson & Capper, 4, Lord-street, Liverpool ...	1	1	0
Forward	£82	15	6

	£	s.	d.
Forward... ...	82	15	6
Thornely, The Misses, Nunclose, Grassendale, Liverpool	2	2	0
Timmis, T. Sutton, Cleveley, Allerton	2	2	0
Toll, J. M., 49, Newsham Drive, Liverpool ...	1	1	0
Walker, Alfred O., Ulcombe Place, Maidstone ...	3	3	0
Walker, Horace, South Lodge, Princes-pk.... ...	1	1	0
Walker, W. H. & Co., Douglas	1	1	0
Watson, A. T., Tapton-crescent, Sheffield... ..	1	1	0
Whitley, E., Clovelly, Sefton Park, Liverpool ...	2	2	0
Weiss, Prof. F. E., Owens College, Manchester ...	1	1	0
Wiglesworth, Dr., Rainhill...	1	1	0
Wragg, Sir W., D.C.L., Port St. Mary, Isle of Man	1	1	0
Wright, C. H., 9, Cook-street, Liverpool	1	1	0
	£100	12	6

Subscriptions for the Hire of "Work-Tables."

Victoria University, Manchester	£10	0	0
University, Liverpool	10	0	0
University, Birmingham	10	0	0
	£30	0	0

THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Dr. IN ACCOUNT WITH EDWIN THOMPSON, HON. TREASURER. **Cr.**

1906.	£	s.	d.
To Balance due Treasurer, December 31st, 1905 ...	2	16	10
,, Printing and Stationery	3	3	2
,, Printing Memoirs	22	10	8
,, ,, Report for 1905	22	7	10
,, Boat Hire and Boat Repairs	1	6	9
,, Books and Apparatus at Port Erin Biological Station	37	0	8
,, Postage, Carriage, &c.	6	9	5
,, Salary, Curator	75	0	0
,, ,, Assistant	27	16	6
,, Sundries	10	3	5
	£208	15	3

EDWIN THOMPSON,
HON. TREASURER.

LIVERPOOL, *December 20th, 1906.*

1906.	£	s.	d.
By Subscriptions and Donations received	98	4	0
,, Amount received from Universities for hire of "Work Tables"	30	0	0
,, Dividend, British Workman's Public House Co., Ltd., Shares	4	19	0
,, Sale of Nat. Hist. Specimens	1	6	6
,, Interest on British Association (1896) Fund ...	38	0	0
,, Bank Interest	0	3	6
,, Laboratory and Class Fees	1	2	0
,, Sale of Guides, &c.	12	11	3
,, Sale of Bottles, &c.	0	7	11
,, Admissions to Aquarium	20	10	4
,, Balance due to Treasurer	1	10	9
	£208	15	3

Endowment Invested Fund:—
British Workman's Public House Co.'s shares £173 1 0

Audited and found correct,
ALFRED LEICESTER.

L.M.B.C. MEMOIRS

No. XIV. LIGIA.

BY

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CONTENTS.

Introduction.

The Isopod *Ligia oceanica* (Linn.) has been selected as the type for this Memoir on account of its comparatively large size, being the largest British Isopod, and also because it is one of the most interesting of the group, being mid-way between the aquatic and terrestrial forms.

The Isopoda, with the Amphipoda, form the sub-order Arthrostraca, and are characterised by being Malacostraca with seven distinct thoracic segments, each bearing a pair of limbs (except the Gnathiidae) and possessing sessile eyes; on account of the last character, they are usually classed together in the sub-order Edriophthalmia.

The Isopoda possess a dorsoventrally depressed body. The thoracic limbs do not bear branchial appendages, as in the Amphipoda, but respiration is carried on by means of the abdominal appendages, which are modified for that purpose, the modification varying in the different tribes. The terrestrial Isopods, the Oniscoidea, are the only members of the group which exhibit such a uniformity in the character of the thoracic appendages as to justify the name.

The following classification of the Isopoda is that given by Sars (1896), each tribe being defined by three characters—those of the first pair of legs, the uropoda, and the pleopoda or abdominal appendages:—

I. First pair of legs cheliform; Uropoda terminal; Pleopoda, when distinctly developed, exclusively natatory - - - 1. *Cheliferae.*

II. First pair of legs not cheliform. (1) Uropoda lateral. (i) Pleopoda for the most part natatory, forming a caudal fan with the terminal segment of the metasome - 2. *Flabelliferae.*

(ii) Pleopoda to a great extent branchial; the Uropoda valve like, inflexed, arching over the Pleopoda - - - - 3. *Valviferae.*

(2) Uropoda terminal. (i) Pleopoda exclusively branchial, generally covered by a thin opercular plate (the modified 1st pair) - 4. *Asellota.*

(ii) Pleopoda for air breathing - 5. *Oniscoidea.*

(iii) Pleopoda when present, exclusively branchial in the adult animal and not covered by an operculum - - - 6. *Epicarida.*

Ligia oceanica belongs to the tribe Oniscoidea, which are characterised by being terrestrial. This tribe includes all the so-called "wood-lice." Their abdominal appendages are fitted for air breathing, but in Ligia there is a very near approach to branchial respiration, as moisture is necessary. The body is oval in shape, and the seven pairs of thoracic appendages are similar in character. *Ligia oceanica* was first described in 1767 by Linnaeus as *Oniscus oceanicus.* Later, in 1798, the genus *Ligia* was created by Fabricius to include the *Oniscus oceanicus* of Linnaeus.

Biology.

Ligia oceanica (Pl. I.) has a wide distribution, and is recorded from the coasts of the British Isles, Faroe Islands, Norway, Denmark, Germany, Belgium, France, Spain, Morocco and America. At Plymouth* I have found *Ligia* most numerous, and of the maximum size, on Drake's Island. At Port Erin they occur in the cliff near the old biological station.

* I wish to express my thanks to the Council of the Marine Biological Association of Great Britain for the use of a table at the Plymouth Laboratory, during the Easter vacation, 1906. Other material for this memoir was obtained at the Marine Biological Station, Port Erin, during the Easter vacations, 1903-4.

They are terrestrial, but require a certain amount of moisture. On the other hand, they are unable to withstand prolonged immersion in sea-water, and still less in fresh water.

They are found just above high-water mark in a zone of varying width. The height of their habitat above high-water mark seems to depend on the nature of their surroundings, which is varied. The greatest number are found in deep narrow crevices in the rocks immediately above high water. Here they can be found in large numbers packed closely together. They also abound in crevices on the side of a quay, hence their name, ‘quay-louse’ or ‘quay-lowders.’ They are also known as ‘sea-carpenters,’ ‘carpenter’ being a local name of the wood-louse. They can be found between the wooden piles of a pier or under the loose stones and rubbish cast up by the tide, which have accumulated in small dark holes. The highest level is attained by those specimens which live in the loose clay and shale forming the cliffs on many parts of our coast, but the specimens living in these conditions do not attain the size of those living lower down in the rock crevices, and are generally of a darker colour.

In St. Kilda, I have found them in the crevices of the boulders on the top of a hill over 450 feet above sea-level. This high altitude may be explained by the fact that the sea spray often reaches that height. It is extremely improbable, however, that the animals go down to sea level to feed. Contrary to the usual rule, the majority of individuals found at this high level were females. I found large numbers of young individuals under rocks between tide marks, and none at the high level, these females probably go down to the sea level to liberate the young from their brood-pouches.

The colour varies from a dark greyish green to a

light dirty brown. In young specimens two light-coloured patches occur on the median line of the dorsal side. The colouration has generally a mottled appearance, the dark portions being due to presence of closely packed chromatophores. In injected specimens a close connection is observed between the terminations of the fine capillaries and the chromatophores. In moulting, the cuticle of the posterior half of the body is shed first, and a short time elapses before the anterior half is shed, so that individuals are often found with the posterior half of the body lighter in colour than the anterior half.

Their food consists chiefly of decaying animal and vegetable substances, and from a study of the contents of their guts, the latter appear to form a large proportion of their diet. In captivity they prefer the weaker members of their own species, but there is not much evidence that this is a natural habit.

They are able to run with great rapidity, coming out from their dark retreats after sunset to feed, at which time they may be caught with the aid of a lantern. The best instrument for capturing them during the day is a fairly long wire, having the last half-inch bent at right angles; by means of this they can be extracted from their narrow crevices.

External Characters.

The body is oval in shape, broadest across the fourth thoracic segment, and gradually decreasing in size towards the posterior end. It is almost twice as long as it is broad. The males are larger than the females, the reverse being usually the case in Arthropods. They may attain a length of 32-34 mm., the width of the thorax reaching 18 mm. The females are more regularly oval in shape

and may reach a size of 26 mm., their extreme width being 11 mm. The dorsal face of the body is moderately convex, and its surface is granulated. The body can be conveniently divided into four regions—1, the head segment or cephalon; 2, the mesosome or thorax, consisting of seven segments; 3, the metasome or abdomen, consisting of five distinct abdominal segments, together with a terminal segment, which is, 4, the telson.

The cephalon is sunk into a depression formed by the forward growth of the epimeral portions of the first thoracic segment. It is evenly convex in front; the posterior border is depressed, the edge being marked by a ridge. The dorsal surface is slightly curved transversely. A pair of large compound sessile eyes are situated laterally, each having a slight reniform appearance from a dorsal view. On the anterior face, which is almost vertical, the minute pair of first antennae are situated, one on each side the median line. To the outside of these are the large and robust second antennae. When moving, the animal holds the large antennae in a forward position, and constantly tests the nature of the surface over which it is proceeding with the very sensitive flagella, appearing to trust for guidance more by this means than by means of its sight. When at rest, they are folded back along the sides of the mesosome.

On the ventral side of the head the mouth-parts form a prominent projection. The mouth is bounded in front by a large transversely-hinged labrum. The sides are composed of the powerful mandibles and two pairs of maxillae. The posterior border is formed by the two maxillipedes, which are imperfectly fused together, forming an apparent lower lip; there is, however, internal to these, a lingua-like bilobed chitinous plate, deeply incised in the middle and having a small median plate;

this forms a true posterior lip. The maxillary excretory organ opens at the base of the second maxilla.

The seven segments of the thorax form the greater part of the animal's body. They are convex on their anterior margins and concave behind. The lateral portions form large epimeral plates, obtusely acuminate, and directed backwards. The segments slightly overlap, and the uniting membrane, which is not impregnated with calcareous salts, sinks into the hypodermal tissues. On the ventral sides, where the epimera join the body, the walking legs or pereiopods arise. The first three pairs of pereiopods are approximately the same size, the last four pairs gradually increase in size. The ventral wall of the thorax is thin and transparent, and strengthened by slightly curved transverse bars. On the ventral side of the thorax of the female, the brood-pouch full of ova is very conspicuous in the breeding season. It is formed by lamellae which arise inside the origin of the five anterior pairs of thoracic appendages and grow ventrally, overlapping the adjacent lamellae distally and laterally. The paired female genital apertures are situated on the inside of the fifth pair of pereiopods. The male genital products are ejected through a pair of styliform appendages on the posterior border of the last thoracic segment, immediately in front of the branchiae.

The metasome or abdomen consists of five segments and the telson, and is about a third of the entire length of the animal. The two anterior segments are narrow, and do not reach the margins, but are lodged in the concave posterior border of the seventh thoracic segment. The three posterior segments have their lateral margins produced into tooth-like backwardly projecting processes. Five pairs of uropoda, which are of the nature of branchiae, are borne on the ventral side of the abdomen.

Each of these consists of an outer 'opercular' lobe and an inner lobe. In the male the inner margins of the outer lobes of the first pair may, or may not, be produced into short spinous processes; the inner margins of the second pair are produced into two long slender styles for copulatory purposes.

The terminal segment or telson is composed of the last two segments of the metasome, which are fused to form a rather broad terminal segment. The posterior edge is evenly rounded; the lateral portions are acuminate and subtend a sinus in which the terminal pair of uropoda arise. Each of the terminal uropoda consists of a fairly stout basal portion, from which the styliform appendages arise. The anus is a longitudinal slit on the ventral side of the terminal segment.

The external apertures are—the mouth, the openings of the maxillary excretory organs on the protopodites of the second maxillae, the openings of the oviducts at the base of the fifth pair of pereiopods, or of the vasa deferentia at the posterior border of the ventral side of the seventh thoracic segment, and the anus.

Appendages.

The **first pair of antennae** (Pl. II., Fig. 1) may be truly called antennules, as they are extremely small, measuring a little over 1 mm. in length. They are situated internal to, and at the base of, the second antennae. They are triarticulate, the terminal joint being quite rudimentary and bearing two terminal groups of small setae.

The **second pair of antennae** (Pl. II., Fig. 2) are long, attaining a length of 25 mm. in the male and 14 mm. in the female; when folded back they extend to the posterior border of the fourth thoracic segment. The protopodite is composed of five joints, the fourth and fifth being the

largest; the fifth joint equals in length the proximal five joints of the flagellum. The flagellum may have as many as 13 or 14 joints, which are setose, the setae being of two sizes.

The **mandibles** (Pl. II., figs. 3, 4) are very powerful and consist of a single protopodite. The point of attachment is D shaped, the curve being internal. From the anterior end of the external border, a powerful tooth-bearing process curves inwards, forming a quadrant-shaped anterior face. The curve of the quadrant is external; the lower side is partially attached and the vertical side bears the mandibular processes. Internally, on this vertical side, there are—a stout molar process, the flat extremity of which is covered with minute closely-set teeth; a small palpiform structure bearing setose bristles, and two stout mandibular teeth separated by a sinus, each being sub-divided into three smaller teeth. The ventral edge of the mandible is produced into a rounded keel, which gradually diminishes in depth towards the posterior edge.

The **first pair of maxillae** (Pl. II., fig. 5). Each maxilla is composed of two lobes. The outer lobe is calcified and much stronger than the inner, which is more flexible. The inner lobe is terminated by three deflexed setose bristles; the outer lobe has a terminal group of short thick spines.

The **second pair of maxillae** (Pl. II., fig. 6) are much modified, being thin and flexible. Each consists of a long protopodite, terminated by an oblique setose joint having internally at its base two setose bristles. The maxillary excretory organ opens at the base of the protopodite.

The **maxillipedes** (Pl. II., fig. 7) are closely approximated on their inner sides and joined at the base, so that

they form an outer lower lip. Each consists of an inner rectangular plate spinose at its anterior margin, and an outer five-jointed palp. The joints of the palp are spinose, each of the four distal joints having on its inner side a setose pad. At the base there is a small lamella.

The **pereiopods** (Pl. II., figs. 8, 9) or ambulatory appendages. Each pereiopod consists of a basal protopodite and an endopodite, which is composed of five spinose joints (ischiopodite, meropodite, carpopodite, propodite and dactylopodite). In the posterior pairs of pereiopods, the carpopodite and propodite are long in comparison with the other joints. The dactylopodite bears two strong recurved claws.

In the female each of the anterior five pairs of pereiopods (Pl. II., fig. 12) subtends a thin foliaceous lamella which curves downwards and inwards, overlapping the opposite and adjacent lamellae, and thus they form a brood pouch in which the eggs are carried. These lamellae are not out-growths of the limbs, but of the sterna.

Abdominal appendages. There are five pairs of abdominal appendages or pleopoda, and a terminal pair of uropoda. Each pleopod (Pl. II., figs. 11, 13) consists of a pear-shaped superior lobe covering a small inferior lamella. In the terrestrial isopods, the outer lobe is termed opercular and the inner branchial. In *Ligia* both are branchial, as will be shown later.

At the base of the outer edge of the superior lobe, there is a small lamella. The edge of the superior lobe is fringed with a border of setose bristles. The second pair of pleopods are modified in the male by having a two-jointed style arising at the base of the inner margin of the superior lobe (Pl. II., fig. 10). The style is long and grooved, and reaches to the fourth pleopod; its distal extremity is slightly swollen and finely pointed. It is

for copulatory purposes. The superior lobe of the first pair of pleopods also may be modified slightly for copulatory purposes. The third, fourth, and fifth pairs of pleopods are very similar in character, the third pair being the largest.

The **uropoda** (Pl. II., fig. 14) are situated at the posterior edge of the sixth abdominal segment or telson, the pleural regions of which are produced posteriorly, thus forming a small sinus in which the uropods can bend laterally. Each consists of a stout basal joint which is widest in the middle and truncated distally. The middle region is thick, narrowing off sharply to the outer edge, and slightly to the inner edge, which is adjacent to that of its fellow. Distally, two setose styliform processes arise. These are about twice the length of the basal portion. During life they are carried in a diverged position, being separated vertically by a wide angle. The inner style has a well-developed terminal spine which is trailed over the ground, and is probably of a sensory nature, as it has similar nervous connections to the sensory bristles of the antennae.

Body Wall, Muscular System and Body Cavity.

The body wall consists of three layers, the outer cuticular layer, the hypodermis and the connective tissue. The cuticular layer is composed of a thin cuticula resting on a thicker layer of chitin, in which two distinct layers can generally be observed (Pl. IV., fig. 3). The chitin is impregnated with salts of calcium, which cause it to have a fairly resistant and brittle texture. Between the segments the chitinous layer is thin. In the middle region of the dorsal side the intersegmental membrane does not dip deeply into the tissues, as it does at the sides. The cuticula bears spines and setae in many regions of the

body. The hypodermal layer is composed of a single layer of cubical cells. Underneath the hypodermis the chromatophores are found. The rest of the body wall is made up of connective tissue, in which groups of large adipose tissue cells occur. These last cells also occur in large numbers on the walls of the alimentary canal, and dorsal to the heart. (Pl. II., fig. 16, *ad. tis.*)

The body cavity (*b.c.*) is a haemocoel, the alimentary canal and other organs being in contact with the blood. A horizontal septum (*sep.*) divides the body cavity into a small dorsal pericardial cavity enclosing the heart, and a large sinus enclosing the other organs.

The muscular system, excluding the muscles of the wall of the gut, heart, &c., consists of three sets of muscles —1, those in connection with the gastric mill; 2, the muscles moving the segments of the body; 3, the muscles moving the appendages.

The muscles are composed of striated muscle fibres. The muscles controlling the gastric mill occupy almost the whole of the cavity of the cephalon and are very conspicuous on opening this. They are attached to the dorsal side of the cephalon, and most of them are inserted into the large lateral cardiac teeth. The muscles moving the segments of the body are also segmented, but the muscle segments alternate with the body segments. On each side of the dorsal line there is a series of longitudinal muscles (*d.l.m.*). The anterior end of each bundle of muscle fibres of this series is inserted immediately behind the anterior end of one segment, and the posterior end is inserted at the anterior border of the succeeding segment. In the lateral regions, where the cuticle dips into the body, a number of oblique muscle bands, which form a series of muscles on each side, have their posterior ends attached to the anterior wall of the cuticular

invagination, and their anterior ends attached to the hypodermis of the middle of the preceding segment. In the lateral, and also the epimeral regions, the body cavity is almost entirely filled up with the muscles moving the appendages; these muscles are attached to the dorsal side of the animal in these regions (*lev. m.*). The longitudinal muscles of the ventral side (*v.l.m.*) have their attachments similar to those of the dorsal side. The joints of the thoracic appendages, like the appendages themselves, are provided with extensor and flexor muscles. The mandibles are provided with a powerful set of muscles, attached to the dorsal side. The proximal ends of the remaining mouth appendages have thickened skeletal rods, forming an internal framework, to which the muscles moving them are attached.

The Digestive System.

The digestive system consists of the alimentary canal and its glands—the salivary glands, and the hepato-pancreas or digestive gland.

The alimentary canal can be divided into four parts—the oesophagus, the stomach, mid-gut and rectum.

The **oesophagus** (Pl. II., fig. 15 *oes.*) opens by a slit-like aperture surrounded by the mouth appendages. Its course is almost vertical, and it opens into the anterior end of the stomach on the ventral side. The oesophagus receives the secretions of the salivary glands.

The **stomach** forms an efficient mill for triturating the miscellaneous substances upon which the animal feeds. It lies in the cephalic and first thoracic segments. The wall of the stomach, which is composed of columnar cells, is lined with chitin, and is folded in a complicated manner; thus a number of chitinous lamellae are formed,

which project into the cavity of the stomach. The dorsal wall of the stomach is almost flat, and is continuous posteriorly with the mid-gut. The anterior end of the stomach is slightly oblique, and when seen from the upper surface is semi-circular. The plates and "teeth" which form the gastric mill are arranged in the following manner. On each of the lateral margins of the anterior end of the stomach a bilobed ampulliform triturating 'tooth' (Fig. 15, *l.c.t.*) arises, and meets its fellow of the opposite side above the opening of the oesophagus. These lateral cardiac teeth are the chief masticatory agents of the gastric mill. Between these, on the anterior wall of the stomach, three teeth fill up the space, a small median anterior tooth (*m.a.t.*) situated between two antero-lateral teeth (*a.l.t.*). Posteriorly, the closure of the entrance to the stomach is effected by a ventral transverse setiferous ridge, the ventral cardiac tooth (*v.c.t.*). In the preceding description, the word 'tooth' has been used to designate a chitinous protuberance of the wall of the stomach, which is covered with short, closely-set, re-curved setae. On the ventral side of the stomach, in the middle region, three tooth-shaped processes arise, their apices directed backwards; they are the median, ventral and ventro-lateral teeth (*v.l.t.*). On each side of the cardiac region of the stomach, a narrow lamella, the lateral cardiac lamella (*l.c.l.*) runs in an oblique direction from the antero-dorsal region to the ventral side, and terminates near the ventro-lateral tooth. In the pyloric region of the stomach, a deep invagination of the dorsal surface forms a broad dorsal lamella (*d.l.*), which extends across the dorsal side and half-way down the lateral sides. Between the lateral portions of the dorsal lamella and the wall of the stomach, two large lamellae (*v.l.p.l.*) have their lateral limits; these

are the ventro-lateral pyloric lamellae. They arise on the ventral side immediately behind the ventro-lateral teeth. Their ventral edges almost meet along their whole length; their lateral edges extend in an oblique direction from behind the dorsal lamella to the ventral side at the anterior end of the mid-gut, where each ventro-lateral lamella terminates in a fine point.

The **mid-gut** (Pl. II., fig. 16 *mid.g.*) extends in a straight line from the posterior end of the stomach to the rectum in the posterior region of the abdomen. It is of uniform width throughout, except at the posterior end, where it narrows considerably, and is surrounded by a sphincter muscle. Three regions can be roughly made out, the arrangement of the epithelial cells of the gut being the means of demarcation. The wall is composed of three layers, an outer muscular layer, a median basement membrane, and internally the epithelium, which is covered by a chitinous intima. This intima is perforated and is shed when the animal moults. The muscular layer is composed of two sets of muscles, an outer longitudinal and an inner circular layer, but this only applies strictly to the anterior end of the mid-gut; further back the muscle fibres become separated by the bulging out of the epithelial cells. The epithelial cells of the gut are very large and contain correspondingly large nuclei. They form a syncytium, as they do not possess complete cell walls, but are separated by inter-cellular fibres, extending from the basement membrane to the intima, and probably of cytoplasmic origin. The arrangement of the epithelial cells varies in different regions of the mid-gut. In the anterior region, which is almost half the entire length of the mid-gut, the cells are irregularly arranged. On the lateral sides they extend in longitudinal rows; the two median ventral rows of cells extend from the anterior end

of the mid-gut to the posterior end. On the dorsal side of the anterior region, in the median line, a typhlosole (*t.y.*) is formed by the floor of a groove being re-invaginated; posteriorly, the sides of the groove widen out into an elongate spoon-shaped structure. The function of the typhlosole is probably not, as is usual, to assist in the absorption of food, but to provide a channel along which the secretion of the hepatopancreas is able to flow to the middle region of the intestine. In the middle region of the mid-gut the epithelial cells exhibit a very regular arrangement. They are arranged in double rows, which run out in an oblique direction from the median line. The rows of cells project into the body cavity, so that grooves are formed between the double rows. In these grooves the muscle fibres are lodged, underneath the blood-vessels from the intestinal arteries. The posterior region is marked by the presence of the sphincter muscle, which separates the mid-gut from the rectum. In the sphinctal region the faecal pellets are formed.

The **rectum** is a short uniform tube opening by the longitudinal slit-like anus.

The **salivary glands**. There are two pairs of salivary glands situated in the cephalon, on each side of, and opening into, the oesophagus. Each is made up of a large number of rosette-like masses of gland cells, which are very similar to the mucous glands described by Allen (1892) in *Palaemonetes*. In section, they have the appearance shown in the figure (Pl. II., fig. 17). Each acinus is made up of a number of concentric cells, in which two regions can be recognised—a peripheral cytoplasmic region containing the nucleus, and a central glandular region. Each of the cells has at its internal apex an intracellular duct (*ic.d.*), which opens into a duct common to the mass of cells (*c.d.*). This duct is probably

formed by a single cell, the nucleus of which can be seen near the centre of the gland (*n.c.d.*).

The **hepatopancreas.** This is also known as the liver, and the digestive gland; the last name describes its true function. In *Ligia* it consists of three pairs of tubules, which extend from the pyloric region of the stomach to the posterior end of the abdomen, where they gradually taper off, and are generally doubled back for a short distance. The three pairs are situated in relation to the intestine, dorso-lateral, ventro-lateral and ventral (Pl. II., fig. 16, *v. hep.*, *vl. hep.*). The muscles of the walls of the distal two-thirds of the tubules are so arranged, that a spiral appearance is produced. The spiral arrangement of the muscles no doubt aids their peristaltic contractions. The tubules of each side open into the pyloric region of the stomach by a single aperture, behind and below the ventro-lateral teeth. The two ventrally placed tubules of each side fuse and then open into the stomach. Anterior to the opening the dorso-lateral tubules curve ventralwards, and fuse with the anterior end of the ventro-lateral tubules. A small tube is given off from the front of the common hepatopancreatic duct, which runs forward for a short distance and ends blindly. The epithelial cells of the hepatopancreas are of two kinds—large secreting cells containing large nuclei, and smaller cells which may be either young secreting cells, or cells of an excretory nature.

The physiology of the digestive system of terrestrial Isopods has been studied by Murlin (1902). He finds that the secretion of the hepatopancreas, which may be liberated by the dissolution of the cell, fragmentation of the cell, or evacuation from the cell, contains ferments, which are able to act upon proteids, carbohydrates and fats.

Vascular System.

Delage (1881) has described the vascular system of *Ligia oceanica* in his Memoir on the circulation of the Edriophthalmia, and, except in a few details, my results confirm his account.

The **heart** (Pl. III., fig. 1, *ht*) is a fairly wide tubular structure, extending from the fifth abdominal segment to the anterior end of the fourth thoracic segment. This posterior position of the heart is correlated with a posterior position of the organs of respiration. Its walls are muscular, and are perforated by two ostia (*ost.*), which are oblique slit-like orifices provided with muscles and two small inwardly projecting flaps. They are situated in the anterior and posterior regions on the right and left sides respectively.

The **pericardium** (Pl. II., fig. 16, *p.c.*) extends from the anterior end of the heart to beyond the posterior end. It receives the efferent vessels from the branchiae, and is continuous with the venous lacunae in the anterior regions of the body. It is separated from the body cavity by a horizontal septum upon which the heart rests.

The heart is continued anteriorly as the median aorta. On each side four arterial thoracic trunks arise. The first pair may be termed the lateral arteries; the remaining three pairs are the fifth, sixth and seventh thoracic arteries, and they arise in the anterior half of the heart.

The **median aorta** (Pl. III., fig. 1, *med. ao.*) runs forward along the dorsal wall of the gut to the cephalic region. In the anterior region of the second thoracic segment two arteries arise from the dorsal side, and run a sinuous course in the hypodermal tissues towards the epimera. In the first thoracic segment a pair of large arteries arise laterally

and run outwards at right angles. Each gives off a large branch which supplies the walls of the stomach, a branch running to the hepatic tubules, a few small arteries to the soft parts, and, after giving off another branch which runs into the epimeron (*ep. art.*), it unites with an artery (i) which is the anterior prolongation of the lateral artery. Immediately on entering the cephalic segment, a small median unpaired artery arises on the dorsal side, and bifurcating, runs in the hypodermis. In front of this the aorta gives off a pair of ophthalmic arteries (*op. a.*) which run outwards to the eyes, giving off many small branches to the soft parts. The aorta now bends down in front of the stomach, where it dilates somewhat, the dilation lying in a cavity on the anterior face of the stomach. This dilation serves as a kind of cephalic 'heart,' as it has on each side muscles connected with a pair of chitinous rods from the anterior face of the stomach. These muscles will aid in the contraction and dilation of the cephalic 'heart,' and so help to pump the blood into the rest of the vessels of the median dorsal aorta; the blood, on account of the posterior position of the heart, would not be driven into these vessels so effectively, if it were not assisted by the action of the cephalic heart.* At the point where the aorta bends, it gives off dorsally a small median artery, and lower down two median unpaired arteries, each of which bifurcates, the superior one supplying the posterior side of the cerebral ganglion (*cer. g.*), and the inferior artery the anterior side of the ganglion. The aorta then bifurcates. Each branch, besides giving off numerous small arteries, which can be better understood by reference to the figure (Pl. III., fig. 2), gives off a large antennary artery (*ant. art.*), and is then continued as the facial

* Contractile vascular sacs occur in the heads of certain insects. Pawlowa (1895) has described them in the heads of certain Orthoptera, and, according to Selvatico, they occur in certain Lepidoptera.

artery (*fac. art.*), which supplies the mandibles and the lateral regions of the face. Neither the injections nor the serial sections showed any oesophageal ring of the nature described by Delage. Several small arteries are given off from the posterior border of the antenno-facial arteries which supply the oesophagus (*oes. art.*) and neighbouring soft parts, as will be seen from the figure. The fact that in many cases these small arteries dilate to an exaggerated extent when injected, may account for the mistake.

The **lateral arteries** (Pl. III., fig. 1, *lat. art.*) run forward and outward from the anterior end of the heart, and in the first thoracic segment each anastomoses with the transverse artery from the dorsal aorta. On the external side of each lateral artery, four thoracic arteries arise (i., ii., iii., iv.), supplying the first, second, third and fourth thoracic segments. On the internal side of the thoracic artery a number of branches are given off which ramify on the walls of the gut (*int. art.*) and hepatic tubules (*hep. art.*). Close to the origin of the fourth thoracic artery a large branch (*gen. art.*) is given off, which supplies the terminal portion of the vas deferens. A number of arteries arise from the dorsal side of each lateral artery, and ramify in the hypodermal tissues.

The **thoracic arteries** (i., ii., iii., iv., v., vi., vii.).—The course of each of the thoracic arteries, with the exception of the sixth and seventh, is somewhat the same. Each runs directly outwards, and, when dorsal to the hepatic tubules, gives off a ventral branch which supplies these. Following the curvature of the dorsal surface the artery curves ventrally; a small artery arises which runs into the dorsal longitudinal muscles. When it reaches the insertion of the limb it bifurcates, the inner branch runs inwards and supplies the ventral surface, the outer branch

soon bifurcates again, the dorsal branch supplying the epimeral (*ep. art.*) region, and the ventral branch is the crural artery supplying the leg (*cr. art.*). The inner branches of the first thoracic artery supplying the ventral surface of the first thoracic segment unite in the mid-ventral line at the base of the maxillipedes, forming a median artery (Pl. III., fig. 2) which runs forwards and gives off paired arteries to the maxillipedes (*mxp.*), second (mx'') and first maxillae (mx'), and terminates in the lingua-like lower lip.

The sixth thoracic artery soon after its origin gives off a branch which runs ventrally, and unites with its fellow of the opposite side in the mid-ventral line of the intestine; from the point of junction a median artery runs forwards and backwards, forming a sub-intestinal artery. From the sides of the sub-intestinal artery paired transverse branches arise in a very regular manner, and run on the walls of the intestine in the oblique grooves which have been described above.

The seventh thoracic artery, after running obliquely backwards for a short distance, gives off an artery which bifurcates and supplies the lateral regions of the intestine. It soon gives off from its posterior side a large artery, the abdominal artery which runs posteriorly; the rest of its course is similar to that of the other thoracic arteries.

The **abdominal artery** (Pl. III., fig. 1, *ab. art.*) of each side runs in an undulating manner, midway between the lateral margins and the median line; from it arise small arteries supplying the intestine, muscles and other tissues. In the third abdominal segment it gives off a ventral branch which supplies the three anterior branchiae and the body-wall. The fourth and fifth pairs of abdominal appendages are supplied by an artery which arises from the abdominal

artery in the fourth abdominal segment. In the last segment an artery is given off internally to the intestine, on the ventral side of which it anastomoses with its fellow and the sub-intestinal artery. The abdominal artery finally terminates in the uropoda.

The **venous system** is lacunar. A large thoracic sinus runs into the abdominal sternal sinus, from which five afferent branchial vessels arise; each of these bifurcates at the base of the branchial appendages, supplying the superior and inferior lobes of the branchiae.

The **vascular system of the branchiae.** The branchiae are supplied by venous vessels from the abdominal sinus. The efferent branchial vessels open into the pericardium by way of the branchio-pericardial canals (Pl. II., fig. 16, *br.p.c.*). The circulation in the superior and inferior lobes of the abdominal appendages, both of which are respiratory, is different. The interior of the inferior lobe of the branchiae (*inf. lam.*) is fenestrated by an irregular system of lacunae, those of the outer side containing venous blood and those of the inner side arterial. On the other hand, the vascular system of the superior lobe (*sup. lam.*) is very definite and uniform throughout the five pairs. It consists of a venous portion (Pl. II., fig. 13, *a.b.v.*), which is ventral (looking at the gill from the anterior face) to the arterial system of vessels (*e.b.v.*). The individual arteries and veins interdigitate in a very complete manner, and the vascular supply is very rich, as will be seen by reference to the figure (Pl. III., fig. 3). On this account, the superior gills cannot be looked upon as being merely opercular in function in this animal, but are certainly respiratory appendages of a very perfect nature.

The blood is colourless and contains nucleated corpuscles which vary in size. As in most anthropods, it is very coagulable.

Nervous System.

The nervous system (Pl. III., fig. 4) is composed of a series of paired ganglia, the ganglia of each pair being closely apposed: the ganglia are connected by distinct commissures.

The supra-oesophageal or cerebral ganglion (*cer. g.*) extends across the space between the eyes, anterior and dorsal to the gut. The ganglion cells have large deeply-staining nuclei, and the fibres arising from them decussate and connect the ganglia. In the supra-oesophageal ganglia several lobes can be distinguished. On the dorsal side there is a large pair of lobes, from the sides of which the optic stalks arise. Each of these optic stalks consists of a proximal lobe, connected by closely apposed parallel fibres with a distal lobe, from which the optic fibres arise and run direct to the retinulae. On the ventral sides of the superior lobes a small pair of median lobes is situated; these are anterior to, and connected with, a larger pair of ventral lobes, the olfactory lobes, from which the large antennal nerves (*ant. n.*) arise. The supra-oesophageal ganglion is connected with the sub-oesophageal ganglion by a pair of peri-oesophageal commissures.

The sub-oesophageal ganglionic mass is perforated near the anterior end by a vertical muscle band. The mouth-parts are innervated by two pairs of nerves (*m.p.n.*), the first of which arises lateral to the perforation, and the second pair posterior to this, and latero-ventral. A pair of nerves (*g.n.*) arise posterior to these and run ventrally to the stomach.

The sub-oesophageal ganglion is connected with the ganglia of the first thoracic segment by a pair of cords, from the middle of each of which a bifurcating nerve arises supplying the muscles of the body.

There are seven pairs of thoracic ganglia (*th. g.*), the ganglia of each pair being closely connected. The pairs of ganglia are connected by commissures, those between the sixth and seventh pairs of ganglia being very short. Each pair of thoracic ganglia gives off a pair of stout nerves, which split into several parts, and supply the appendages. From the middle of the length of the commissures connecting the ganglia, nerves arise which innervate the muscles of the body.

In *Ligia* the abdominal ganglia are all fused into a single ganglionic mass (*ab. g.*) situated in the anterior region of the abdomen. In the Isopoda all stages are found, from the original separate condition of the abdominal ganglia to the fused condition occurring in *Ligia*. From the abdominal ganglion nerves arise, which supply the appendages and muscles of the abdomen; a large pair of nerves run from the posterior end of the ganglion to supply the uropoda.

A small median nerve runs between the commissures connecting the thoracic ganglia from the sub-oesophageal ganglion to the seventh pair of thoracic ganglia. It has been termed the 'sympathetic' nerve, but there is no evidence that it is of such a nature.

Sensory Organs.

The **eyes.**—As the eyes of the *Ligia oceanica* are different from the eyes of other Isopods, which have been described by Parker, Beddard and others, their structure will be given in detail.

They are compound and sessile, occupying almost the whole of the lateral region of the head. In the mature animal each eye consists of upwards of 500 ommatidia. The corneal cuticula is facetted. The corneal facets of the

central ommatidia are plano-convex, with the flat side internal; those in the peripheral regions have the inner side slightly convex also.

In a single ommatidium (Pl. IV., fig. 1) the following parts can be recognised. The internal face of the corneal cuticular facet (*corn. cut.*) is covered with two thin cells, the subcorneal hypodermal cells (*s.c. hyp.*) The nuclei of these cells can be seen in the figure. Internal to these are the nuclei of the two cone cells. (*nuc. con.*). Each of the cone cells secretes a hemispherical transparent mass (*con.*), the two segments with their flat surfaces apposed form the cone. The cone cells surround the cone segments, and on the proximal side form two sub-cylindrical, transparent accessory cones (*acc. con.*), which is the most interesting and exceptional feature of this eye. The cone cells are surrounded by two pigment cells (*pg. c.*) which completely invest the upper half of each ommatidium. The retinula consists of six retinulae cells, and not seven, as stated by Beddard (1888). In this it agrees with *Idotea inovata*, which also has six retinulae cells (Parker, 1891). The retinulae cells (*ret.*) have fibrillar axes which are continuous with those of the nerve fibres. The six nuclei of the retinulae cells are situated at their proximal ends (*nuc. ret.*). The rhabdom consists of six individual rhabdomeres, each rhabdomere (*rh.*) remaining attached to the retinula cell which forms it, and separate throughout its length from the other rhabdomeres. There is a dense mass of pigment (*pg.*) between each of the rhabdomeres and its retinula cell. This may have been formed by the retinula cell, which also contains a large amount of pigment, or it may have resulted from an intrusion of a process from one of the pigment cells. The latter view is probably the correct one. The nerve fibrils of the retinulae pierce the basement membrane (*b. m.*); those

of a single ommatidium fusing on the proximal side to form a single nerve fibre (*op. n. f.*), which runs direct to the distal portion of the optic lobe.

Sensory bristles.—On the flagellae of the large antennae there are a number of sensory bristles on each segment. These have been figured before by Němec (1895). Each bristle (Pl. IV., fig. 3, *s.b.*) is enclosed by a sheath (*sh*), which is continuous with the rest of the cuticula (*ctla.*). The thick inner layer of chitin is pierced by a canal, the lumen of which is continuous with that of the bristle. From the bristle, by way of the canal, a number of delicate fibres (*n. f.*) run and communicate with a number of nerve fibres lying beneath the hypodermis (*hyp.*). These sensory bristles are probably the most important organs of sense which the animal possesses, as the antennae are continually in use. Besides their undoubted tactile function, they may take the place of auditory organs.

The inner of the two styles of the uropods, as described previously, are probably of a sensory nature.

Excretory System.

The excretory system may be studied in two ways—by feeding animals on food mixed with ammonium carminate or indigo-carmine, and by injecting aqueous solutions of these substances into the body cavity. The latter method is the most satisfactory, but should be supplemented by the first. The injections are made with a hypodermic syringe (or a pipette drawn out to a fine point). The animal is injected on the ventral side, at the base of one of the appendages, and may be killed from 3 to 48 hours after the injection and fixed in absolute alcohol or Flemming's solution.

The excretory organs of Isopods have been studied

by Bruntz (1904), with whose results my observations on *Ligia oceanica* are in agreement. There are four kinds of excretory organs, two of which are nephrocytes, either grouped or scattered; the third is a definite nephridium, or 'kidney,' and the fourth, certain cells in the hepatopancreas.

The maxillary kidneys, or nephridia, occur in the basal portion of the second pair of maxillae. They consist of two parts - the saccule and labyrinth. The saccule is a slightly convoluted tube, which Vejdowsky considers is a remnant of the obliterated coelom. It is blind at one end, and opens at the other into the labyrinth. The cells forming the wall of the saccule are large and of excretory nature. The labyrinth communicates with the exterior by an aperture at the base of the second maxilla.

The cephalic nephrocytes are situated at the bases of the first antennae. They occur along the ventral and lateral sides of the levator muscles of these appendages. These cells are fairly large; the protoplasm is homogeneous and contains a number of granules.

The branchial nephrocytes occur in the abdominal region, dorsal to the attachment of the branchiae. There are five pairs of groups of branchial nephrocytes. They are situated in two lateral lines, each line running above the points of attachment of the abdominal appendages, and their outer edges reach the bases of the epimeral plates. Each group borders on two segments, the first group bordering on the last thoracic and first abdominal segment. The nephrocytes lie on the sides of the branchio-pericardial canal (Pl. II., fig. 16, *br. neph.*). They are large cells, and the cytoplasm, which is vacuolated, contains many granules. Němec considers the branchial nephrocytes to be a syncytium, but the cell boundaries are very distinct, as Bruntz also noticed.

Bruntz found that certain small cells of the epithelium of the hepatopancreas, called 'Fermentzellen' by Weber, pass coloured solutions such as acid fuchsin from the body cavity into the lumen of the duct and are excretory in nature.

Reproductive Organs.

The reproductive organs of *Ligia oceanica* are simple in structure. In the male (Pl. IV., fig. 4) there are three pairs of elongate fusiform testes (*t.*), each being prolonged into a fine filament. They are situated dorsal to the intestine in the second and third thoracic segments. The three testes of each side are placed in series, and open into a vas deferens (*v. d.*) of uniform width throughout the greater part of its length. The vasa deferentia are usually white and extended. They are situated on the dorso-lateral sides of the intestine, and extend in a horizontal direction to the seventh thoracic segment. In this segment they narrow abruptly to form two narrow ducts, which curve ventrally round the hepatic tubules; each opens at the base of a styliform appendage (*st. ap.*) situated on the ventral side of the seventh thoracic segment, on one side the median line. The testes are divided by slight constrictions which indicate different regions of spermatogenesis in the interior. In the process of spermatogenesis the spermatids unite in varying numbers to form colonies, their cell walls disappearing. The nuclei elongate considerably, and very fine fibres are formed which may be attached to the nuclei, but on account of their extreme tenuity the writer is unable to be certain on this point. Miss Nichols found the same difficulty in the spermatogenesis of *Oniscus asellus*. The whole sperm colony, as it may be termed, together with the cytoplasmic fibres, is surrounded by a protoplasmic

sheath. The anterior end of this is flagellate, and by contractions of the slightly muscular walls of the testis it is forced into the vas deferens. Here the sperm colonies are found bound together in masses (Pl. IV., fig. 5). The substance which causes this cohesion is probably secreted by a number of large cells which are situated in the anterior end of the vas deferens near the openings of the testes.

In the female the ovaries are very conspicuous in the breeding season, entirely filling up the dorsal part of the body cavity. They lie at each side of, and beneath, the heart, and extend from the first thoracic segment to about the fourth abdominal segment. They are usually filled with eggs of approximately the same size. A short distance behind the middle of the ovary a thin walled oviduct is given off. This opens to the exterior by a small longitudinal slit at the base of the fifth pair of pereiopods, immediately at the base of the brood pouch lamellae, these being the last pair of brood pouch lamellae.

The ova are large, oval in shape, and contain a large amount of yolk. In copulating, the male walks on to the back of the female and grasps the anterior thoracic segments with the first three pairs of pereiopods; copulation may last one or more days. After the eggs are extruded, they are carried about by the female in the brood pouch, where they develop; the young remain for a short time in the brood pouch.

Development.

The development of *Ligia oceanica* has been studied by Nusbaum. According to Nusbaum, the early cleavage is discoidal, although McMurrich has found superficial or centrolecithal segmentation in the Isopods which he has investigated. The first cleavage cell becomes separated

from the rest of the yolk and lies on the periphery, where it continues to divide, and so forms a cap of blastoderm cells, no cleavage cells remaining in the food yolk. The starting point corresponds to the point where invagination takes place later, that being at the posterior end of the ventral side of the embryo.

After the formation of the blastoderm a thickening is formed, corresponding to the future ventral side. This thickening is the germ disc. Shortly afterwards, three divisions of the germ disc make their appearance. Two anterior paired portions (Pl. IV., fig. 6, *a.m.*) represent the formative region of the mesoderm; a median thickening (*end.*) situated posterior to, and between these, represents the fundament of the endoderm. The germ band is next formed by a probable forward growth of the mesoblast rudiments below the ectoderm, the ectoderm increasing in thickness. Three pairs of buds arise; these are the rudiments of the limbs, and this stage (Pl. IV., fig. 7) corresponds to the Nauplius stage. Behind these rudiments, and in front of the anal aperture, is a mesoblastic area, termed the formative area (*f.z.*), from which the remaining segments of the body will develop. The arrangement of the mesoderm cells in the formative area is extremely regular.

At the beginning of the formation of the mid-gut a number of cells (vitellophags) leave the endoderm and wander inwards; they do not take any part in the formation of the mid-gut, but assist in the disintegration of the yolk. The mid-gut is formed from two layers of cells which arise from the endoderm rudiment; these lie below the germ band, and gradually grow round the yolk, each being concave on its inner surface. By means of a ventral median piece they unite in the anterior region, and finally enclose the yolk by growing round to the dorsal side, so

that the yolk becomes surrounded by mid-gut epithelium. Two flask-shaped vesicles are constricted off on each side of the anterior end of the mid-gut. These are the rudiments of the hepatic tubules, which are formed by their backward growth, and a longitudinal constriction and division of each rudiment into three parts.

The rudiments of the thoracic limbs are biramous (Pl. IV., fig. 8), a fact which is used in support of the theory that the Crustacea have descended from a schizopodous ancestor. In *Ligia* the inner limb (endopodite) alone develops, the exopodite being suppressed.

The nervous system arises as a continuous whole from the ventral thickening of the ectoderm between the limb rudiments. The thoracic ganglionic rudiments are paired, but those of the abdominal segments are unpaired. Three pairs of ganglia form the supra-oesophageal ganglion, namely the optic, first and second antennal. The sub-oesophageal ganglion is formed by the fusion of four pairs of ganglia—the mandibular, first and second maxillar and the maxillipedal. There are rudiments of seven ganglia in the abdomen; rudiments also of seven pairs of abdominal appendages are originally formed.

The heart is formed by the fusion of two dorso-lateral layers of cells, crescentic in section, and lying dorsal to the gut. The limbs develop successively from before backwards. In the earlier stages of development the embryo has a dorsal curvature, but later it becomes ventral. On hatching, the young isopod possesses six pairs only of thoracic appendages, which are imperfectly segmented, and not setose; the cephalic region of the young animal is large in proportion to the rest of the animal. It leaves the brood pouch of the female, and after several moults attains the adult form.

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Explanation of Plates.

Plate I.

Ligia oceanica (Linn.), dorsal view, × 4.

Plate II.

Fig. 1. First antenna seen from the side: much enlarged.
Fig. 2. Second antenna of left side seen from above.
Fig. 3. Left mandible seen from below.
Fig. 4. Teeth and molar process of mandible from the posterior side.
Fig. 5. First maxilla of left side.
Fig. 6. Second maxilla of left side.
Fig. 7. Left maxillipede.
Fig. 8. First pereiopod of male.
Fig. 9. Seventh pereiopod of male.
Fig. 10. Second abdominal appendage (or pleopod) of left side of male, showing copulatory style; anterior view.
Fig. 11. Fourth abdominal appendage (pleopod) of male, posterior view, showing the inner lamella.
Fig. 12. Third pereiopod of female, attached to the epimeral plate, showing one of the brood pouch lamellae arising from the sternum internal to the appendage.
Fig. 13. Fourth abdominal appendage of female, anterior view. The inner lamella can be seen by transparency; also the afferent (*a.b.v.*) and efferent (*e.b.v.*) branchial vessels.
Fig. 14. Uropod, showing sensory process at the tip of the inner style.

Fig. 15. Interior of the right side of the stomach. The stomach has been opened by a vertical section, a little to the right of the median line so that the median ventral tooth has been removed. The greater part of the cardiac region of the stomach is surrounded by a layer of connective tissue. (*a.l.t.*) antero-lateral tooth; (*d.l.*) dorsal lamella; (*hep.*) hepatopancreatic tubule; (*l.c.l.*) lateral cardiac lamella; (*l.c.t.*) lateral cardiac tooth; (*m.a.t.*) median anterior tooth; (*oes.*) oesophagus; (*v.l.t.*) ventro-lateral tooth; (*v.l.p.l.*) ventro-lateral pyloric lamella; (*v.c.t.*) ventral cardiac tooth.

Fig. 16. Transverse section through the abdominal region. The abdominal appendage of the left side is omitted. (*ad. tiss.*) adipose tissue cells; (*b.c.*) body cavity (haemocoel); (*br. neph.*) branchial nephrocytes; (*br. p. c.*) branchio-pericardial canal; (*d.l.m.*) dorsal longitudinal muscles; (*epim.*) epimeron; (*ht.*) heart; (*inf. lam.*) inferior lamella of gill; (*lev. m*) levator muscle of appendage; (*mid. g.*) mid-gut; (*p.c.*) pericardium; (*sep.*) septum forming floor of pericardium; (*sup. lam.*) superior lamella of gill; (*ty.*) typhlosole; (*vl. hep.*) ventro-lateral hepatopancreatic tubule; (*v. hep.*) ventral hepatopancreatic tubule; (*v. l. m.*) ventral longitudinal muscles.

Fig. 17. Transverse section of two of the rosette-like salivary glands. The left section shows the common duct (*c.d.*) of the glandular cells, formed by the uniting of the intracellular ducts (*ic. d.*); *n.c.d.* is the nucleus of the cell which probably forms the common duct.

Plate III.

Fig. 1. Dissection of the arterial system from the dorsal side. The main arterial trunks are drawn somewhat larger than they are naturally. For the sake of clearness, details of the anatomy have been omitted. (*ab. art.*) abdominal artery; (*cer. g.*) cerebral ganglion; (*cr. art.*) crural artery; (*ep. art.*) epimeral arteries; (*gen. art.*) genital artery; (*hep. art.*) hepatic arteries; (*ht.*) heart; (*int. art.*) intestinal artery; (*lat. art.*) lateral artery; (*med. ao.*) median aorta; (*op. a.*) ophthalmic artery; (*ost.*) ostium; (*vent. art.*) ventral artery; (i-vii) thoracic arteries.

Fig. 2. Arteries of the left side of ventral surface of head and first thoracic segments. (*ant. art.*) antennal artery; (*fac. art.*) facial artery; (*mand. art.*) mandibular artery; (*mx′.*) artery of first maxilla; (*mx″.*) artery of second maxilla; (*mxp.*) artery of maxillipede; (*oes. art.*) oesophageal artery. Other references as in the preceding figure.

Fig. 3. Afferent vessels of the superior lamella of one of the abdominal appendages injected with indigo-carmine from the sternal sinus.

Fig. 4. The nervous system, seen from above after the removal of the muscles and viscera. (*ab. g.*) abdominal ganglion; (*ant. n.*) antennary nerve; (*g.n.*) nerve to stomach; (*med. n.*) median nerve; (*m.p.n.*) nerves of mouth appendages; (*op. l.*) optic lobes; (*sub-oes. g.*) sub-oesophageal ganglion; (*Th′. g.*) first thoracic ganglion.

Plate IV.

Fig. 1. Longitudinal section of a single ommatidium. (Drawn with the camera lucida.) (*acc. con.*) accessory cone; (*b.m.*) basement membrane; (*con.*) cone; (*corn. cut.*) corneal cuticula; (*nuc. con.*) nucleus of cone cell; (*nuc. ret.*) nucleus of the retinular cell; (*op. n. f.*) optic nerve fibre; (*pg.*) pigment; (*pg. c.*) pigment cell; (*ret.*) retinular cell; (*rh.*) rhabdomere; (*s-c. hyp.*) sub-corneal hypodermal cell.

Fig. 2. Transverse section of ommatidium showing the six retinulae cells and their rhabdomeres.

Fig. 3. Longitudinal section through the cuticle of a segment of the flagella of the second pair of antennae to show a sensory bristle and its nerve supply. (*ch.*) thick layer of chitin; (*ctla.*) cuticula; (*hyp.*) hypodermal layer; (*n.f.*) nerve fibrils; (*s.b.*) sensory bristle; (*sh.*) sheath of sensory bristle.

Fig. 4. Generative organs of the male. (*t.*) testes; opening into (*v.d.*) the vas deferens, which opens externally by the styliform appendages (*st. ap.*).

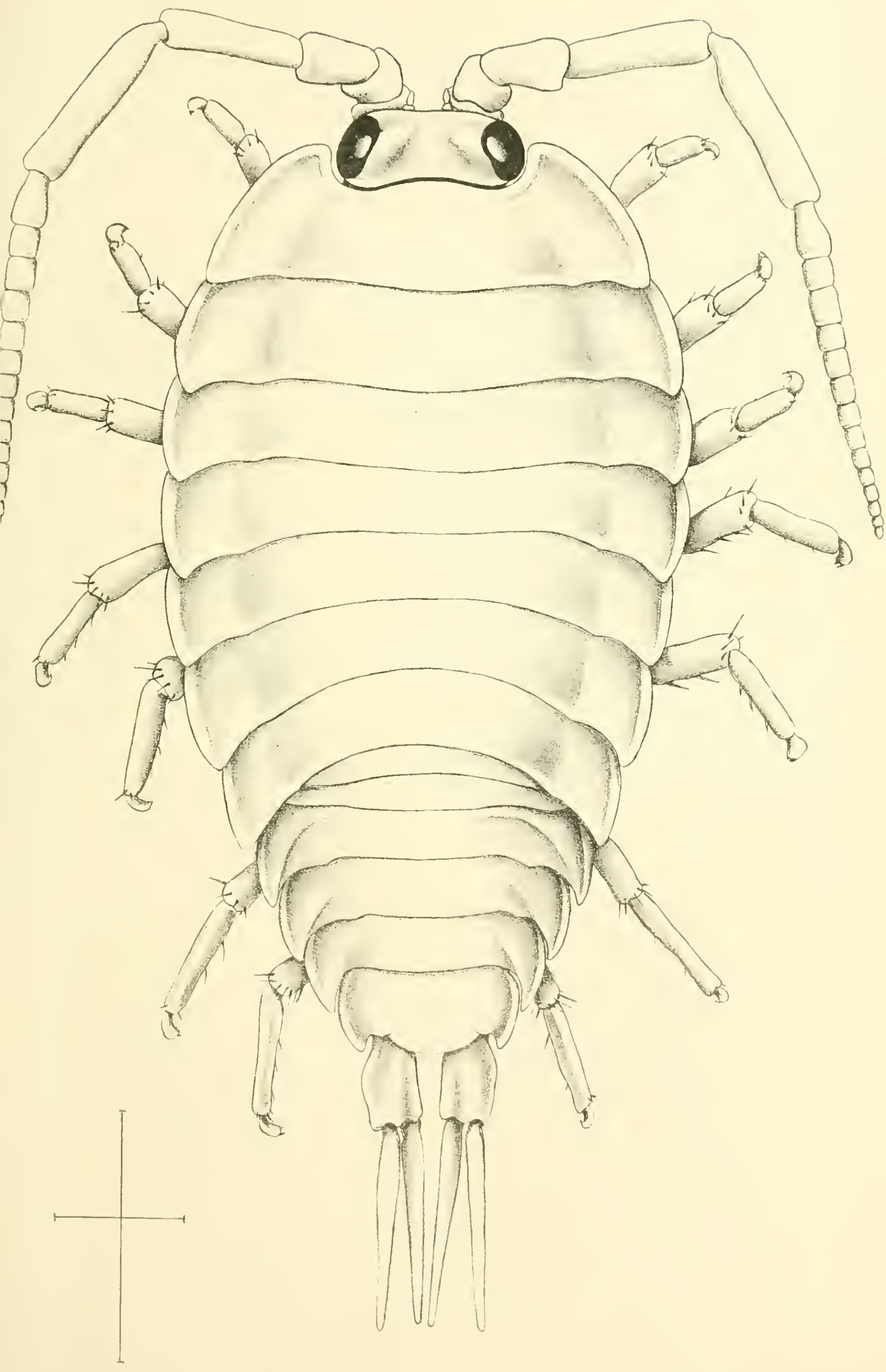
Fig. 5. A collection of 'sperm-colonies' as they are found in the vas deferens, in the cohesive substance secreted by the latter.

Fig. 6. Early stage in the development of the egg, showing the cleavage of the germ disc into the two antero-lateral mesoderm fundaments (*a.m.*) and the median posterior endoderm fundament (*end.*).

Fig. 7. The 'nauplius' stage of the development of *Ligia*, showing the three naupliar appendages. (1.*a.*) and (2.*a.*) the first and second pairs of antennae, and the mandibles (*mand.*); (*end.*) endoderm fundament; (*f.z.*) formative zone; (*op.*) optic lobe.

Fig. 8. A later stage in the development, showing the elongation of the formative and the formation of appendages, also the rudiments of the ganglia. (*an.*) anus; (1. and 2. *mx.*) first and second pairs of maxillae; (*mxp.*) maxillipedes.

The last three figures are after Nusbaum.



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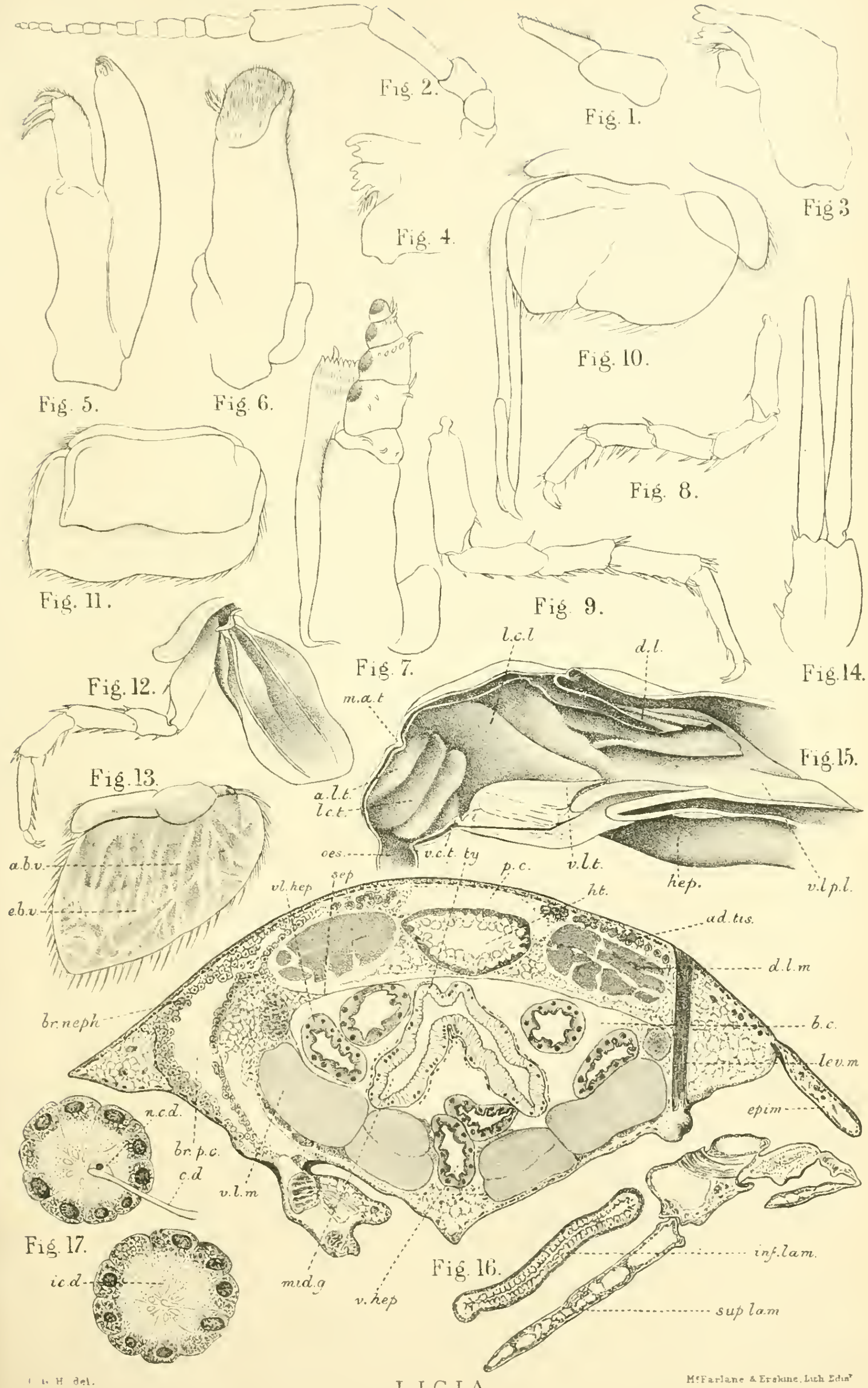

LIGIA

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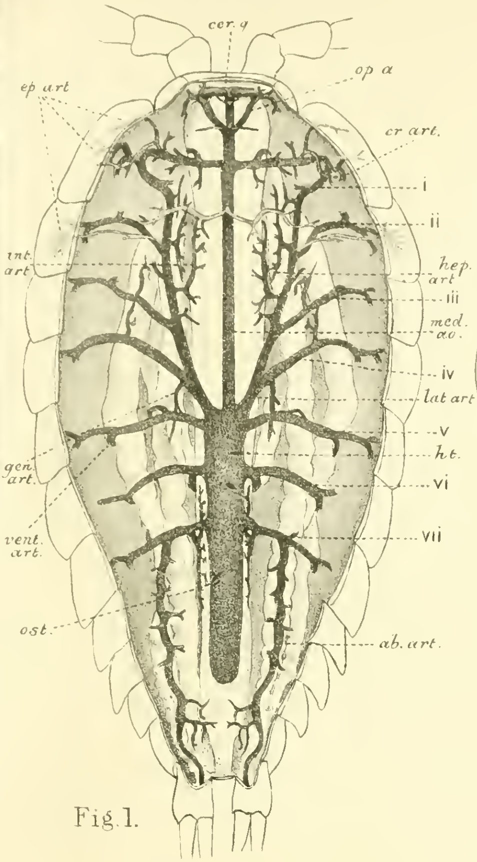

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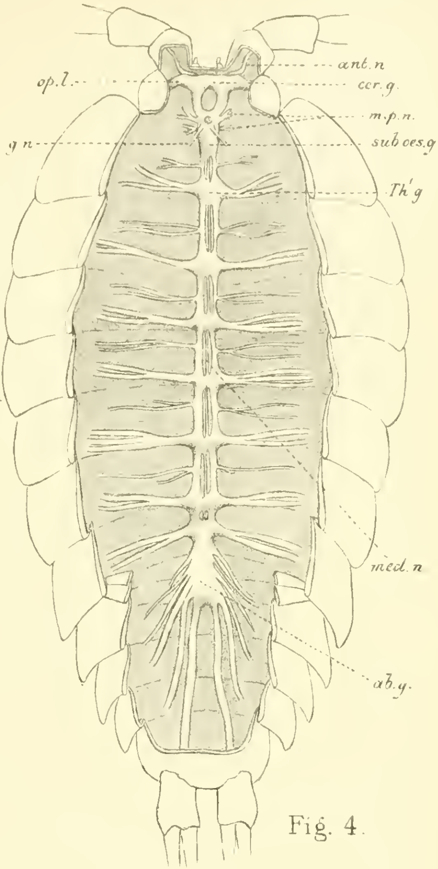

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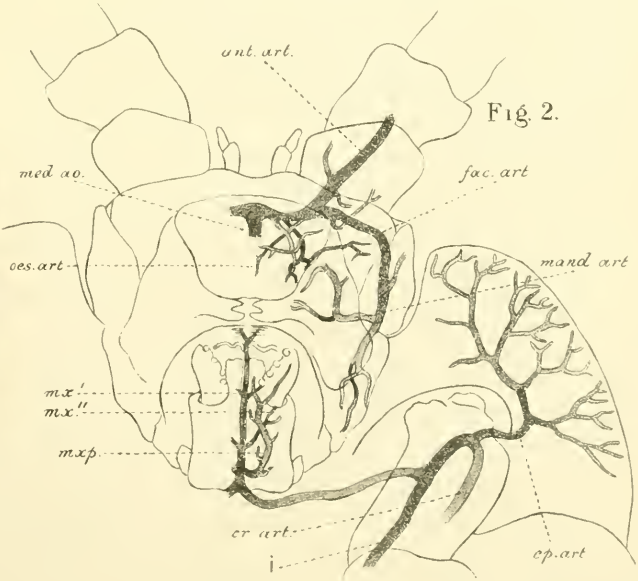

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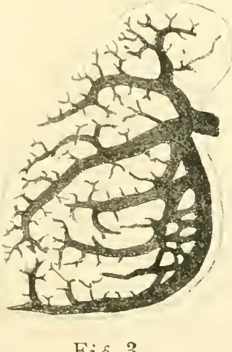

Fig. 3.

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LIGIA.

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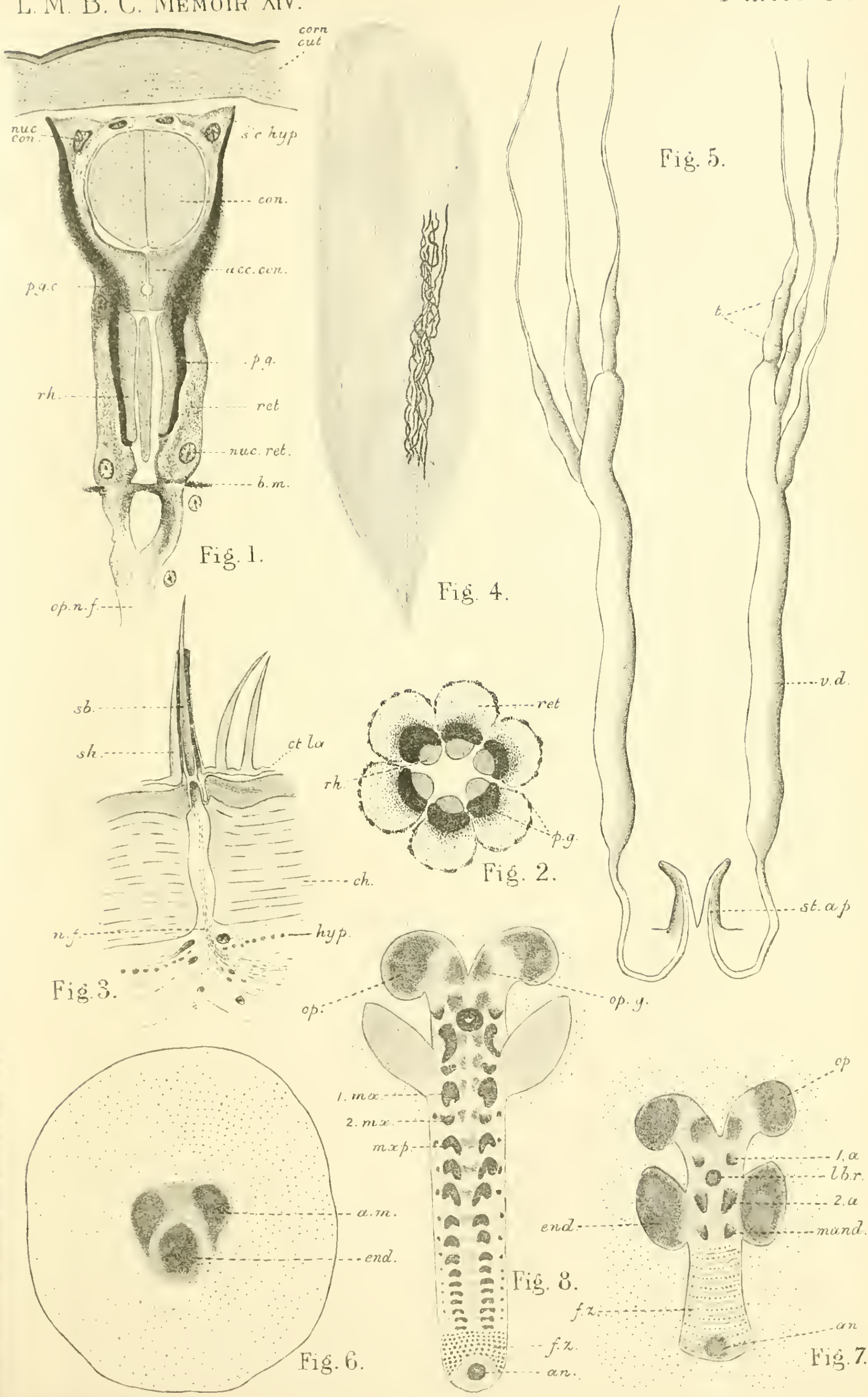

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REPORT on the INVESTIGATIONS carried on during 1906 in connection with the LANCASHIRE SEA-FISHERIES LABORATORY at the University of Liverpool, and the SEA-FISH HATCHERY at Piel, near Barrow.

Drawn up by Professor W. A. HERDMAN, F.R.S., Honorary Director of the Scientific Work; assisted by Mr. ANDREW SCOTT, A.L.S., Resident Fisheries Assistant at Piel; and Mr. JAMES JOHNSTONE, B.Sc., Fisheries Assistant at the Liverpool Laboratory.

(With plates, charts and figures in the text.)

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INTRODUCTION AND GENERAL ACCOUNT OF THE WORK.

During 1906 the system of quarterly reports which was referred to in the Introduction of the last Annual Report has been continued with the view of bringing the more important matters dealt with in the laboratory before the notice of the Scientific Sub-Committee with as little delay as may be, and has also served to keep the Committee generally better informed as to the progress of the scientific work.

The Board of Agriculture and Fisheries have sent various specimens to the Liverpool laboratory to be examined. Their Inspectors have visited the laboratory

more than once during the year, and a report on the work carried out has been furnished, at their request, to the Board.

A considerable part of the work is of a routine nature and does not differ much from that reported on last year. Mr. Scott has been chiefly occupied at Piel with flat-fish hatching, with the fisheries classes, and with making as complete an estimate as possible of the minute floating life in the sea all over the district. Mr. Johnstone's chief work has been, as usual, the conducting of the fishermen's classes at Piel, the bacteriological examination of samples of shellfish, as required, and the investigation of the parasites and diseases of fish in the Liverpool laboratory. The marked fish experiments, the Hensen net experiments and the collection of the hydrographic samples have also occupied part of the time of both Mr. Johnstone and Mr. Scott. Some of these lines of inquiry will be commented upon now, and others will be found discussed more fully in the sections of the report that follow.

Flat-Fish Hatching.

Mr. Scott's report shows that nearly 14 millions of plaice and flounder fry were distributed last season. As I have already pointed out on previous occasions, our numbers in this output do not, and cannot, increase. The really quite inadequate provision of tanks at Piel is strained to the uttermost, as many plaice and as many flounders are accommodated as can possibly be kept healthy. I am satisfied that Mr. Scott is doing all that can be done in the matter, and that until a spawning pond and a better equipment of hatching tanks is provided there is no hope of increasing the output.

I may remind the Committee that in the Port Erin Hatchery we have a second establishment adding annually

to the stock of young flat-fish in the Irish Sea. Last spring over five million plaice fry were hatched from six million eggs and were successfully set free in the open sea to the south and west of the Isle of Man.

As before, a certain number of the larvæ have been left throughout the summer in the open-air spawning pond at Port Erin and reared through their metamorphosis into young plaice. It is very interesting to note that of these young fishes, all of the same age, while those left in the larger pond, under more natural conditions, had attained by September (say five months' growth) a size of up to nearly five inches in length (the average of 12 being $3\frac{1}{2}$ inches), a few that had been placed on exhibition in the Aquarium in a white enamelled basin, although regularly fed, in the same time grew to only one inch. A few thousand put in the smaller western part of the pond were sampled on October 3rd, 162 days after hatching. Twelve taken at random varied in length from $1\frac{1}{8}$ inch to $2\frac{7}{8}$ inches, the average length being $1\frac{3}{4}$ inch.

The classes for fishermen at Piel laboratory have been held as usual, and with the usual success. The details are given in Mr. Scott's Report below.

Sea-Fish Hatching in Norway.

I print two interesting statements sent to me by Captain Dannevig and Mr. K. Dahl, dealing with the supposed results of adding artificially hatched cod larvæ to certain Norwegian fjords. These investigators not only write from very different points of view, but unfortunately they do not deal with exactly the same series of observations, so that it becomes difficult to compare their results, and, in fact, on a superficial examination it might be supposed that no correspondence could be traced between

the two series of statements. If, however, we remove the additional observations dealt with by Mr. Dahl, and which were apparently not a part of the joint enquiry agreed upon, some facts remain in common, although they may be interpreted in different ways. For example, Dannevig shows that in 1903, before his Flodevigen larvæ were liberated, the Sondeled Fjord yielded 426 cod larvæ (to over 100 hauls of the seine =4 per haul), while the two following years (after the planting of the fry), averaged, gave 1,328, or about 13 per haul. Removing the July-August observations, which do not appear in Dannevig's experiments, these numbers agree with what is shown in Dahl's table, and indicate an increase to about three times the amount. In the case of the Hellefjord, where smaller numbers were dealt with, the correspondence of results is not so clear, and some further explanation is perhaps necessary; but, averaging both localities, Dannevig shows the increase after planting to about double the quantity, which is represented graphically in his diagram. Captain Dannevig, of course, attributes the increase to the liberation of the artificially hatched larvæ, while Dahl from his additional observations with tow-nets, &c., comes to the conclusion that the cod eggs and larvæ naturally present are so affected in their abundance and distribution by currents in the water which vary from year to year, that the fry added can have no appreciable effect, and that such increases or decreases as may be noted from year to year are due to natural reproduction and hydrographic influences. The impression produced by reading these two papers is, I think, that the observations are still too few to lead to any sure conclusions; but it may be useful to point out that, even if Dahl's interpretation is correct, it does not follow that Dannevig's operations are useless. If the addition of 50

or 60 millions of young cod adds to the stock in that fjord, the benefit may be great even if from other causes the average per haul in the following year shows a decrease. An addition has been made to the natural stock of fry—whatever that is—and that may well have a beneficial effect upon the future population whatever, as the results of various factors, that may come to be.

Plankton Investigations.

During the past year a larger number of plankton gatherings have been obtained by tow-nets than ever before, and these have been very carefully examined by Mr. Andrew Scott. Four hundred gatherings in one year from a limited area like the Irish Sea ought to give useful information, and the value of the series is increased by the fact that in so many cases we have gatherings taken from different parts of the area on the same day, amounting to practically simultaneous observations. The advantage of having several centres of work in the district—the steamer, the bailiffs, Piel and Port Erin--from which observations can be taken is obvious in an enquiry like this; and Mr. Scott's lists and tables given below will be seen to be an interesting contribution to a subject that is still imperfectly known. Before any far-reaching conclusions can be drawn from plankton gatherings it is clear that we must be sure what it is that our nets are catching, and how far the samples caught on different days or at different localities or with different nets are comparable, and can be said to be representative of any time or place. With a view of testing such points I chartered a small steamer for two months last summer and took almost daily gatherings, with several different kinds of tow-nets, during August and September. In all, about 80 samples were collected in 40 days, and the main result is to show a

puzzling diversity, which indicates that further work is necessary.* I hope to continue this work myself from a small steam-yacht during the coming spring and summer. In addition to the equipment previously used I have recently obtained a Nansen closing deep-water tow-net with which observations will also be taken.

Dr. Travis Jenkins has recently arranged to permit of the steamer taking periodic trips along a fixed line for the purpose of obtaining gatherings with the large Hensen quantitative net. These trips will take place monthly, the line of stations is from Piel Gas buoy to the Great Orme Head, and Mr. Scott will carry on the work. The series was started in January, 1907, and the second trip is now taking place.

Hydrographical Observations.

The scheme of hydrographic observations which was proposed in the Introduction to the last Annual Report was duly sanctioned by the Committee, the necessary apparatus was obtained, and the practical work was started in summer. The observations are carried out by Mr. Johnstone on the steamer, and the samples of sea-water obtained are analysed in the laboratory by Dr. Basset, to whom we are very much indebted for the time and trouble he is kindly giving to the work. It is too soon yet to come to any conclusions, so I merely place on record the following list of observations made:—

Three cruises were made during 1906:—

(1) 4-5 July, 1906.
(2) 18-19 Sept., 1906.
(3) 13-14 Nov., 1906.

* A fuller account of these observations was given in an address delivered to the Biological Society, and published in the Annual Report of the Liverpool Marine Biology Committee in December. I do not repeat the information here because I am convinced that further work is required and that I shall be able to give a better account of the whole subject by waiting till next year.

On each cruise two lines of stations were worked :—

(1) Piel Gas Buoy, Walney Ch. to Maughold Head.

(2) Calf of Man to Holyhead.

Four " stations " were worked on each line :—

(1) 6 miles N.W. from Piel Gas Buoy.
(2) 15 ,, ,, ,, ,,
(3) 24 ,, ,, ,, ,,
(4) 32 ,, ,, ,, ,,
and (5) 7 miles S. by W. from Calf of Man.
(6) 16 ,, ,, ,, ,,
(7) 25 ,, ,, ,, ,,
(8) 33 ,, ,, ,, ,,

It was decided that observations should also be made in Carnarvon and Cardigan Bays during the third cruise, but bad weather prevented these from being carried out.

Bacteriological Work.

A good deal of Mr. Johnstone's time has been occupied with questions of sewage contamination of shell-fish beds on the Lancashire and North Wales Coasts. The investigation of such cases, both on the ground, where adequate samples have to be taken, and also subsequently, as a matter of bacteriology in the laboratory, is of very great importance and some difficulty. The responsibility attaching to such work is very great, because of the possible danger to public health on the one hand, and the possibility of injuring a prosperous industry on the other. The Scientific Sub-Committee have had several carefully considered reports from our laboratory during the year, and the results of Mr. Johnstone's examination of the Morecambe and the Conway mussel beds are given below.

Other Work.

The experiments with marked fish are fully discussed in Mr. Johnstone's article below, and the other sections of this report dealing with the Parasites and the Food of fishes, the Ichthyological notes and the Faunistic notes explain themselves and require no further comment.

As the present winter is a critical time in the history of sea-fisheries research in this country—on account of the approaching termination of the five-year period of the International North Sea Investigations, and the hope that on the conclusion of that work Government may be willing to subsidise similar work on other parts of the coast—I have thought it desirable to draw up, for the information of the Committee, a statement of the present situation, as it now appears to me. I print this article on "Sea-Fisheries Research in England" with the view, not of criticising any particular plan or piece of work, but of pointing out that the present juncture seems to give an opportunity of uniting all interests round the three coasts of England in a comprehensive national scheme.

W. A. Herdman.

Fisheries Laboratory,
University of Liverpool,
February 5th, 1907.

SEA-FISHERIES RESEARCH IN ENGLAND (A statement bearing on the present situation).

By W. A. Herdman, F.R.S.

The position of this country in connection with Sea-Fisheries investigations at the present juncture is most interesting; and the decision which H.M. Government will be called upon to make, early in 1907, as to the measure of official recognition, control and support to be given to such investigations on different parts of the coast will be of unusual importance, since it cannot but have a profound effect upon future work and knowledge bearing on fishery questions. In the recent history of the subject the only period approaching the present in interest and importance is the winter and spring of 1901-2. It may be useful to recall that at that time, five years ago, two quite unusual events had taken place. One of these was the announcement, on January 31st, that the then Government had given its adhesion for a period of several years to the International Scheme of North Sea Investigation; and the second was the presentation to Parliament, and subsequent publication, of the Report of a Committee of Government Officials, Fisheries Experts, and Zoologists, to whom had been referred the whole question of scientific investigations in connection with British Sea-Fisheries.

This latter body, the "Ichthyological Research Committee," was appointed by the President of the Board of Trade (the Government Department which at that time included Fisheries) in August, 1901, and meetings for the examination of witnesses and discussion of results were held during the twelve months to

September, 1902. The Report of the Committee, which was issued as a Parliamentary paper about the end of the year, recommended a comprehensive National Scheme of investigation centring, as regards England, in the Government Department, co-relating and uniting the energies of the various administrative and investigating bodies, and giving the necessary support to a marine laboratory on each of the three coasts.

Legislative action upon these various recommendations was, however, postponed, because the Government had meanwhile become engaged to participate for a period of years in the International scheme of investigations; but the Report of the Ichthyological Committee was received with marked approval by most, if not all, of the Sea-Fisheries Authorities of England and Wales; and in answer to representations made at successive annual statutory meetings, the President of the Board (formerly of Trade, latterly of Agriculture and Fisheries), in the chair, has stated on the various occasions that at the conclusion of the limited period for which the International work had been guaranteed, the question of a National Scheme would be considered, and the claims of the Local Sea-Fisheries Districts would then receive attention from the Government.

For example, Earl Carrington, the present President of the Board of Agriculture and Fisheries, at the meeting in the House of Lords on 14th June, 1906, after expressing his sympathy, stated that he "would leave no stone unturned" in trying to get from the Treasury some money for such a National Scheme as was desired, and he ended by appealing to the Local Authorities present to give him all the support in their power when the time came [see Blue-book, Cd. 3063, p. 10]. Within the next few weeks is clearly the

proper time for compliance with Lord Carrington's request, since the five-year period of the International work expires in July, 1907, and if any part of the money then set free is to be secured for Local Sea-Fisheries investigation it ought to be included in the estimates which will shortly be prepared for Parliament. Under these circumstances, it seems desirable that a somewhat detailed statement should be made, avoiding as far as possible critical and controversial matters, but setting forth plainly the present position and the alternatives that are now placed before the country.

The International Scheme.

Some years ago a group of distinguished foreign meteorologists and biologists put forward a scheme for international co-operation in the hydrographic and biological investigation of certain North-European seas (North Sea, Baltic, Norwegian Sea, &c.), in the hope that the data thus acquired might throw light upon weather prognostication in the interests of navigation and commerce (a matter of some importance to the more northern nations) as well as upon the conditions and prospects of the fishing industries in those seas. The matter was taken up by the Swedish Government, and on their invitation Great Britain, Germany, Russia, and other countries bordering upon the North Sea and the Baltic, agreed to participate in the investigation and to contribute towards the expenses of a central organisation.

Great Britain, however, only consented in the first instance to take part in the work and contribute to the expenses for a period of three years; but later on the time was extended so as to complete the five

years for which other nations were pledged, but at the same time it was made clear to the International Council that our Government did not contemplate any further continuance of the work. ("The delegates are requested to impress upon their foreign colleagues that it is not the intention of His Majesty's Government to participate in the investigations on the present footing after 22nd July, 1907."—Blue-book Cd. 3165, p. 9).

The cost has been great—the British share of the total expense amounted to about £70,000, or £14,000 per annum, of which £5,500 was allotted to work done off the Scottish Coasts and £5,500 to that on the East and South Coasts of England—the remainder being required for expenses of administration and the central organisation. No part of the money was expended on Ireland, nor on the Western Coasts of England and Wales. The Scottish portion of the work, it was arranged, should be carried out by the officials of the Fishery Board for Scotland under the Scottish Office; and the English portion by the Marine Biological Association, a well-known scientific body controlled by a council of between 30 and 40 members, under the presidency of Professor Ray Lankester, and having a large laboratory and headquarters at Plymouth, with a smaller branch establishment at Lowestoft for the special purposes of the International work.

The Local Sea-Fisheries Committees around the coasts of England had no part in the work, nor had the Government Department chiefly concerned in the subject (the Board of Agriculture and Fisheries).

The International investigations have been controlled by a Council ("Conseil Permanent International pour l'Exploration de la Mer"), the Executive of which is a "Bureau," having its seat at Copenhagen and its Central

Laboratory at Christiania. The Bureau consists of an inner circle of three ordinary members, viz.:—

Dr. W. Herwig (Germany) as President,

Dr. O. Pettersson (Sweden) as Vice-President,

Dr. P. P. C. Hoek (Holland) as Secretary;

and an outer circle of four extra-ordinary members,

Capt. Drechsel (Denmark) as Hon. Treasurer,

Dr. F. Nansen (Norway), Director of the Laboratory,

Prof. O. von Grimm (Russia), and

Prof. D'Arcy W. Thompson (Scotland).

Thus Great Britain is not represented on the inner circle, and England has no representation even on the outer body, although England's interests in the North Sea Fisheries are admitted to be paramount.

The International investigations have been carried on with energy and enthusiasm for the last four and a half years, and the reports that have already appeared—including "Rapports et Procès-verbaux," "Bulletins des Résultats," "Publications de Circonstance" issued by the "Conseil Permanent International," and the Blue-books and other publications of our own and other Governments—form an enormous body of literature, containing much that is of the greatest interest to scientific men, and some of which will, no doubt, one day find its place in a scheme of knowledge that is useful in connection with practical fisheries questions.

It is scarcely necessary to point out that a clear distinction can be drawn between a scheme of investigation (1) as a piece of pure scientific research, and (2) as a practical enquiry which will solve within a given time and by given means questions of importance to particular industries. Of the interest and importance, to science, of the International work as a piece of pure research there ought to be, and probably there is, no

doubt. We must all be in sympathy with the work from that point of view. It is oceanographic research of the most desirable and fascinating kind, which is bound to yield qualitative results of great interest to biologists—and probably also to hydrographers. But there is the greatest difference between (1) such qualitative results which add certain new facts to science, and in regard to the economic importance of which all that can be said is that each and every scientific fact will some day find its application and may then become of commercial importance to mankind, and (2) immediate quantitative results given as the outcome of investigations directed to particular practical problems. Viewed as the former, the International results are valued contributions to science; the facts are useful whether few or many, whether they establish any definite principles or not, and the conclusions put forward are welcome if regarded only as scientific speculations which stimulate and suggest and may lead eventually to definite proof. It is when put forward as quantitative results directly applicable to practical questions that grave doubts arise as to the adequacy of the methods to solve the problems and as to the sufficiency of the observations to justify the economic conclusions.

I have no desire to assume a critical aspect, or to try to find defects in the International or any other useful work. All such investigations must have defects, and I much prefer to appreciate the valuable contributions to scientific knowledge made by the International Council: they have added greatly to the sum of our data in the Hydrography and Biology of the North Sea. If those who prosecute and those who support this investigation will declare that they regard it as scientific research undertaken jointly with foreign savants with the object

of acquiring certain scientific data—which may, or may not, have a bearing upon fishery questions—then I, for one, will cordially approve of the enlightened action of our Government in endowing scientific research to that extent. But the British Delegates at the International meetings have made it quite clear that our country took part in the scheme with the expectation of obtaining practical results in the fixed period of years.* How unlikely it is that any such results will be obtained by the methods, in the time, can only be realised by those who have had considerable experience of the irregularity of distribution of fish and other living things in the sea, and the difficulty of obtaining samples that are truly representative of an extensive area.

It is obvious that if we are to have the benefit that was promised from international co-operation, any conclusions arrived at should be put forward with the full authority of the International Council, and as the deliberate opinion of the united wisdom of the experts; but it is evident from the published results that a considerable amount of difference of opinion already exists. In both the hydrographical and the biological sections we find the conclusions of some of the investigators rejected by their fellow-workers [see Blue-book, Cd. 3165, p. 6, and paragraph 9 on p. 7; also Cd. 2966, p. 47]. As a matter of pure science this is of no great importance, it may be helpful rather than harmful, since it tends to promote research and discovery; but when it is a question of conclusions that may be applicable to the industries

* In the Report of the Christiania Conference, in 1901, we are told, under the heading "Guarantees of Practical Results," that it was agreed "that the work of summarizing the practical results of the scientific explorations should not be left to the end of the five years' period, but should be undertaken from year to year. Consequently, by now we ought to have the "practical results" of the first four years in our hands.

the case is very different. If any of these conclusions are liable to be made a basis for action by the Government or by any Fisheries Authority, they ought obviously to be subjected to the same open discussion and free criticism as would take place in the case of an ordinary scientific theory. This will, no doubt, be the case eventually with the International results, but in the meantime it is most undesirable that conclusions or opinions expressed authoritatively should be put forward unsupported by the detailed observations on which they are based.

THE ICHTHYOLOGICAL RESEARCH COMMITTEE.

At the same time that Great Britain undertook to participate for a limited number of years in the International investigations, the Committee above referred to was sitting at the Board of Trade charged to report "as to the best means by which the State or local authorities can assist scientific research as applied to problems affecting the fisheries of Great Britain and Ireland." This Committee, which reported in 1902, consisted of four representatives of Government departments (the late Mr. S. E. Spring-Rice, of the Treasury; Mr. Pelham, of the Board of Trade; Sir. C. Scott-Moncrieff and Sheriff Crawford, of the Scottish Office); and four zoologists or fisheries experts (Mr. Walter E. Archer, of the English Fisheries Department; the Rev. W. Spotswood Green, of the Irish Fisheries Department; Professor J. Arthur Thomson, of Aberdeen; and Professor W. A. Herdman, of Liverpool).

After the detailed examination of many witnesses representing science, the fishing industries, and all other interests concerned, and some discussion of results, the four experts were requested by their colleagues to

draw up a Memorandum as to the relations of the International scheme to the most pressing fishery problems and the methods to be adopted in the solution of such problems. This Memorandum was adopted by the Committee and is printed on p. xxii. of the Report (Blue book Cd. 1312).

If the argument in this Memorandum of the Ichthyological Committee is correct, grave doubt is cast upon the validity of any results which might be obtained solely by methods proposed in the "Christiania Programme"—the revised or second official programme of the International work. It is evident from an examination of the official publications of the International Council that some such doubts must at a later date have occurred to those engaged in the work. For example, in August, 1902, at the first meeting held after the memorandum above referred to had been presented, the Council resolved that it was not possible to undertake the biological portion of the "Christiania Programme" in its totality, and decided to restrict the investigation to certain problems [Cd. 1313, p. 102]. Again, in 1904, it was recognised that the methods hitherto adopted were inadequate for the solution of these problems, and the instructions to the British delegates [Cd. 2966, p. 32] caused still further alteration in the International programme. Then, in 1905, the quarterly "seasonal cruises" (in February, May, August and November), which were a very fundamental point in the original scheme, and which had been criticised in the Report of the Ichthyological Committee, were apparently recognised as being inadequate and were supplemented by more frequent observations [Cd. 2966, pp. 54, 172, 174, 175 App. B, also Cd. 3165, p. 14].

Thus the progress of events during the last four

years has, on the whole, tended to show that the criticisms put forward in the Report of the Ichthyological Research Committee were well founded, and served to indicate the direction in which the International Scheme of work has required to be modified. Under these circumstances, we turn now with the more confidence to the constructive portion of that Committee's Report in order to enquire how far the recommendations then made will meet the needs of the situation at the present juncture. The Committee recommended a National Scheme of fisheries research and organisation, into the constituent elements of which they entered in considerable detail. This scheme provides what has long been felt and often expressed as a great need in England, viz., a Central Fisheries Board, having at its command laboratories, vessels and scientific men on all the coasts, and it also endeavours to ensure the sympathy and utilise the energies of the District Committees, by giving them adequate representation on the Central Body and by delegating the work on the several coasts to the local investigators.

The points dealt with in the Report are (1) Statistics, (2) Expert Staff, (3) Laboratories, (4) Vessels, (5) Central Authority, and (6) Co-operation with Scotland and Ireland; and the recommendations under these heads may be briefly summarised, with comments, as follows:—

(1) Statistics.—The Committee insist upon the necessity for much fuller and more accurate statistics as to the results of the commercial fisheries than are now supplied. Returns must be obtained from the masters of fishing vessels, and it is very desirable that full returns of all fish caught, giving the localities and other particulars, should be made compulsory.

The official system of collection of fisheries statistics has been improved at many ports since 1902, but further

development around the coast generally is much to be desired.

(2) Expert Staff.—In the first place a staff of trained assistants is required at the principal fishing ports to deal with the returns obtained from the boats, to inspect the catches landed and to select samples for further examination. Certain observations can be made and certain particulars noted by such assistants carrying on statistical work at the ports, but it is not suggested that they need be laboratory biologists. Then, secondly, the samples selected, along with the statistical and any other information, should be sent for more detailed examination to the recognised marine laboratory of that coast, there to be dealt with by the Director and his scientific assistants.

(3) Laboratories.—The Ichthyological Committee point out that "the fishery interests of the East Coast, the South Coast and the West Coast of England, respectively, are, to some extent, distinct," and they propose that these three coasts should be treated independently, each having it own marine laboratory, staff of workers, surveying vessel, and representatives on the Central Authority. It is recommended that, if possible, arrangements be made so that (1) the Marine Biological Association Laboratory at Plymouth be officially recognised as the headquarters for scientific fisheries work on the South Coast, say from the Estuary of the Thames to the Bristol Channel; (2) that the Liverpool Marine Biological and Fishery Laboratories be similarly the centre for work on the West Coast ; and (3) that a laboratory be established to perform similar functions on the East Coast. If the new Marine Biological Station which is now being erected at Cullercoats, in the Northumberland Committee's District, had then been in existence, there can be no doubt that the

Ichthyological Committee would have recommended that that laboratory should be recognised as the centre for work on the East Coast. It is possible, also, that, under

FIG. 1. Sketch Map of the British Islands, for the purpose of indicating the position of the chief marine laboratories and sea-fish hatcheries, and the proposed division of the coast of England into three great fisheries districts—The East coast, the South and the West.

the conditions now existing, the recommendation might have been added that the Lowestoft Laboratory should be

taken over, if that is possible, from the Marine Biological Association, and should be the home laboratory of the Fisheries Department of the Board of Agriculture and Fisheries, in order to furnish the Government Department with the laboratories, experimental tanks and scientific assistants, without which the officials cannot be expected to carry on original investigations.

On the other hand, if the view be held that the Government Department should not itself undertake any actual marine investigations, but should delegate such work to the different laboratories round the coast, a natural division of the area would be for the Marine Biological Association, with its laboratories at Plymouth and Lowestoft, to conduct the explorations from Cornwall to the Wash, while the District Committees North of that point, with the laboratory at Cullercoats, would undertake the remainder of the East Coast. The exact details of such divisions are not of prime importance, the essential point being that the Ichthyological Committee in making their recommendations in regard to laboratories for the three coasts made use to the fullest extent of existing institutions.

(4) Vessels.—Each of the three coasts, it is proposed, should have a research or surveying steamer of the type of a modern steam trawler, especially fitted up for scientific investigations and carrying on its work in connection with the laboratory of that coast.

(5) Central Authority.—The Ichthyological Committee recommend the formation of a "Fishery Council for England," consisting of representatives of (*a*) the Board of Agriculture and Fisheries, (*b*) the local Sea-Fisheries Authorities of the three coasts, and (*c*) the scientific men in charge of the three marine laboratories. This Fishery Council would be, to some extent, analogous

to the Fishery Board for Scotland, but more suitable in other respects to England, where strictly local fisheries are more common than in Scotland, and where local needs have to be more closely studied. The Council would, it is hoped, be so representative as to unite the various fisheries' interests and ensure the co-operation of the different organisations, local and central, now working at fishery problems. It is suggested that the Fishery Council should meet monthly, or more often as occasion may require, under the Board of Agriculture and Fisheries, to formulate and control schemes of investigation, to receive reports on work done on the three coasts and co-relate observations, to recommend the allocation of grants to the laboratories, and, generally, to report to Government, through the Board of Agriculture and Fisheries, on the needs and results of the work carried on by the steamers and the laboratories.

INTERNATIONAL CO-OPERATION.—In order to secure uniformity of action between the Fisheries organisations in England, Scotland and Ireland, to prevent overlapping of areas and of investigations, and to arrange as to any sub-division of work between the three countries, or with foreign nations, the Ichthyological Committee recommend that quarterly conferences should be held between representatives of the Fishery Council for England, the Fishery Board for Scotland and the Irish Fishery Department. "The meetings of this conference would give an opportunity to the members of the three Central Authorities to compare notes, to obtain information as to what is being done in the three countries, and to make suggestions to the three Central Authorities as to what particular work should be undertaken by each" (Report, p. xv.). It is only to this extent—Quarterly Conferences—that the Ichthyological

Committee have considered it practicable to constitute one Central Fisheries Department for the United Kingdom. We may quote finally paragraph 39 from the "Concluding Observations" of the Report:—"The Committee believe that by carrying out these recommendations the State would recognise, co-relate and control the work of the existing independent organisations in the United Kingdom, and would build up a scheme of Fishery Research of a thoroughly practical character, centring, as regards England, in the Board [of Agriculture and Fisheries], and, at the same time, in intimate contact with the fishing trade, the District Committees and the scientific laboratories round the coast."

The Present Situation.

The adoption of these recommendations made in 1902 by the Ichthyological Committee's Report would, it is believed, satisfy the wishes and claims of the District Committees on the East and West Coasts, but it seems improbable that that course would satisfy the Marine Biological Association, and it is quite incompatible with a continuance of the International work as at present carried on. It seems doubtful, however, whether the officials of the Marine Biological Association desire that the International work should be continued under its present organisation. The Council of the Marine Biological Association have recently issued various circulars and reports, and have organised a deputation to the Chancellor of the Exchequer, asking H.M. Government to give them control, not merely of the whole amount they have been administering annually in the North Sea investigations, but also of an additional £2,000 a year for the Plymouth Laboratory, making a total annual grant of £8,000, with no limit of time specified. It is very

difficult, from these reports and the speeches of prominent members of the Council, to understand exactly what are the intentions or wishes of the Marine Biological Association in regard to the International Council and Bureau. They ask quite definitely to be allowed to continue the International investigations; but a passage in the speech by the Chairman of the M.B.A. Council suggests that they are contemplating the severance of their present connection with the International Council. If that is the case, it is surely of primary importance to all concerned in the discussion of these questions to know under what organisation they propose to work. If they do not desire to continue under the direction of the "Conseil Permanent International," are they prepared to adopt the recommendations of the Ichthyological Research Committee to such an extent as will satisfy the claims of the Sea Fisheries District Committees of the East and West Coasts, or is it their intention to claim all the money that has recently been expended by England on the International work, and such additional grant as the Government may give, to spend after July on their own work under their own organisation, in independence alike of the International Council and of the constituted Sea-Fisheries Authorities around the coast? Surely their position in this matter should be made quite clear before their claim to the administration of the whole of the English portion of the International fund can be discussed.

In one of the circulars that has appeared during the winter, it was suggested that the M.B.A. Council might be increased by allowing the Board of Agriculture and Fisheries, the National Sea Fisheries Protection Association, and the different Sea-Fisheries Committees, who have established marine laboratories for scientific

research, and, if necessary, other bodies concerned, the right to nominate one or more members of Council.

It must be pointed out that although this may seem to be offering an opportunity to Sea-Fishery Committees of participating in the regulation and administration of Sea-Fisheries research under their scheme, it is not doing so in any real sense or on an adequate scale. The Council of the M.B.A. consists of about 38 members (including the President and Vice-Presidents, who have presumably a right to sit on Council), so that unless a considerable number of representatives of, say, the Government department on the one hand and the Local Sea-Fisheries Authorities on the other, were added, so that all elements were fairly balanced, no real power would be given. But such a greatly enlarged Council would be unwieldy and impracticable; in fact, the Council of the M.B.A., as it stands, is too large a body, besides being unsuitable in other respects, for such specialised work as is contemplated.

The Marine Biological Association is a distinguished Scientific Institution, one of the primary purposes of which is the promotion of research in pure science and the higher education of young Zoologists from the Universities. Academically it holds a high position and its educational value in pure science might be of national importance. It is on those lines that, in the opinion of some of its own members and loyal supporters, it ought to develop rather than in connection with the fishing industries. As a scientific and educational institution it is worthy of all possible encouragement and support, and it is to be hoped that H.M. Government will give a liberal subsidy to the Plymouth laboratory and other similar institutions for purposes of research in pure science.

But with the view of collecting, examining and co-ordinating such scientific researches at different centres and of applying them to specific fishery problems, and of making use of the money set free by the termination of the international work and such other funds as H.M. Government can devote to this important national object, it is essential to have a small working body of experts such as was recommended in the Report of the Ichthyological Committee—men who have been, and are, actively and sympathetically in touch both with the various fishing industries and the various methods of scientific research that can be applied to them. As examples of such experts may be taken Prof. McIntosh and Dr. Fulton, in Scotland; Mr. W. S. Green and Mr. E. W. L. Holt, in Ireland; and Mr. Walter E. Archer, in London. The academic Zoologists on the Council of the M.B.A. are all eminent men in their own special lines of research, but would, most of them, I hope, be unwilling to lay claim to expert knowledge on fishery problems.

It is, surely, unfortunate in the interests of science that the Council of the Marine Biological Association should have recently appealed to scientific men in general at the Universities to sign a petition addressed to the Lords Commissioners of H.M. Treasury in support of the work carried on by the International Council and its continuance in the hands of the Marine Biological Association. It is probable that some, at least, of the more or less distinguished Zoologists, Botanists, Geologists, Physiologists, Pathologists, Astronomers, Chemists, Mathematicians and Anthropologists who have lent their names for this purpose have done so with very imperfect knowledge, if any, of the methods and results of the international work, and very possibly in complete

ignorance of the other side of the case as represented by the Local Sea-Fisheries Committees.

District Committees.

The administration of the Sea-Fisheries around our coasts is now entrusted to District Committees, who, under the Board of Agriculture and Fisheries, have large powers in regard to the supervision, regulation and promotion of the industries. Most of these Committees have undertaken some investigations, and a few of them have done much. They have secured the advice and assistance of scientific men, have helped in the establishment of marine laboratories, and have expended considerable sums upon investigations, both by special steamers and otherwise.

It would, in my opinion, be a fatal mistake to do anything that would tend to discourage such excellent local effort or to divorce administration from scientific investigation. All sound regulation of the Fisheries must be based upon accurate and detailed investigation. As the administration has to be applied locally, the investigation must be conducted locally. Every part of the coast, every shellfish bed, has its own problems. It is impossible to apply general principles or results obtained elsewhere without an intimate knowledge of the local conditions. The Sea Fisheries Committees which have been conducting such local investigations have a strong claim, not, perhaps, to be relieved entirely of the expense of this necessary work, but to receive a substantial contribution from the national purse. The local effort has in some cases been very considerable, funds have been raised, services have been given gratuitously and the work has been carried on energetically and successfully. There is no reason to suppose that the local subsidies will

fail, but they ought to be largely supplemented. The District Committees have been urging their claims for a grant from the Treasury for at least five years, and have received many assurances of sympathy and of ultimate substantial help.

The present juncture seems thus to afford an opportunity, such as has not previously occurred, of formulating a comprehensive scheme which will deal with all parts of the coast and unite all interests. Anything approaching to a monopoly in science is most objectionable. There cannot be a monopoly in work, so there ought to be none in State recognition and support. The North Sea investigations are welcome additions to science, the work of the Marine Biological Association is worthy of all the support that can be given both by scientific men and by the Government, but neither of these organisations covers the whole ground, and any scheme which does not embrace the three seas of England and utilise to the full the various laboratories and Fisheries Authorities around the coast, more or less on the lines of the Ichthyological Committee's Report, will fail to solve the present problem of Fisheries research in Great Britain.

SEA-FISH HATCHING AT PIEL.

By Andrew Scott.

The results of the hatching work in the spring of 1906 are very similar to those obtained in previous years. The present accommodation for adult fishes is always strained to the limit of safety. Any marked increase in the output could, therefore, only be secured by considerable additions to the existing tanks.

The first eggs were observed on February 17th, but no fertilised ones were obtained till March 14th. The spawning lasted for practically two months. During that time fourteen millions of flounders' eggs were collected and one and a half millions of plaice eggs. The incubation of the eggs was carried on in the usual manner in the Dannevig apparatus, and yielded nearly fourteen millions of fry. The fry were liberated at intervals, well out in Morecambe Bay. It has been customary to set free the parent fish in the Barrow Channel at the end of each hatching season, but the fate of these fish has always been unknown. At the end of the hatching season in 1905 Mr. Johnstone marked some of the large plaice from the tanks and set them free between Lancashire and the Isle of Man. None of these have been recovered. Another attempt to find out the movements of the fish was made by marking some of the flounders in 1906. These were set free outside the Barrow Channel. A few of the marked flounders were recaptured by fishermen and returned to us, and are dealt with by Mr. Johnstone in his report on fish marking. During the autumn of 1906 the local

fishermen reported that several very large plaice had been captured in the Barrow Channel. The sizes of these fish far exceeded those of any flat-fish they had previously taken. The men suggest as a very probable explanation that they were some of our liberated plaice. Capt. Wright also secured one or two of these large fish while trawling for flounders for the tanks. It is quite possible, then, that the large plaice set free at the end of each season remain in the vicinity.

When selecting adult plaice for the tanks we depend largely on their size, and hitherto all under fourteen inches in length have been rejected. This size is probably a good average one, but it is evidently not always the minimum even for females. This was clearly demonstrated in the spring of 1906. In March, when out with the "John Fell" collecting material for the classes, two mature female plaice were captured in the same haul. One of these fish was nineteen and a half inches long, and the other was only ten and a half inches. Later on in the month two more mature plaice were captured in the same area as the previous ones. The latter were both eleven and a half inches long. These fish were brought alive to Piel. They all produced eggs which fertilised and developed quite normally. The fish were captured between Walney and Isle of Man in the area known as the "Top end of the Hole," on March 13th and 20th. According to McIntosh and Masterman* plaice appear to have very definite spawning grounds, always well offshore and at a depth of about twenty fathoms. Under artificial conditions we find it is possible to get them to spawn in much shallower water. At Port Erin the fish spawn freely in a pond with a maximum depth of ten feet. At the Bay of Nigg Hatchery, belonging to the Fishery

*British Marine Food Fishes, p. 364.

Board for Scotland, spawning takes place under similar conditions. Our small fish tanks at Piel are only about four feet deep, and we find the fish mature quite normally. During the spring of 1906 we found that some of the adult plaice, collected in Luce Bay in the autumn of 1905, matured when kept in water fourteen inches deep. The fish actually spawned in that depth of water, but the eggs were not fertilised. Very ripe female dabs collected in March, and brought alive to Piel, discharged their eggs in shallow tanks only ten inches deep. In the latter case the eggs were probably too far advanced to be retained by the fish when subjected to the greatly altered conditions of pressure. In the other case, so far as reproduction is concerned, the only apparent difference due to confinement is a slight retarding of the maturation of the eggs. We find from the tow-nettings taken in the open sea that plaice eggs were taken in Cardigan Bay on January 23rd, 1906, and off the Liverpool North-west Lightship on the 31st. The occurrence of one plaice egg in Cardigan Bay on December 15th, 1905, and the capture of a spent female plaice in the same bay on January 26th, 1906, has already been recorded by us. Fertilised eggs under artificial conditions were secured at the Bay of Nigg Hatchery on January 20th,† and at Port Erin Hatchery on February 20th, 1906.‡

The following tables give the number of eggs collected and of the fry hatched at Piel, and set free on the dates specified:—

† Twenty-fourth Annual Report Fishery Board for Scotland, part iii, p. 112.

‡ Twentieth Annual Report of the Liverpool Marine Biology Committee, p. 17.

Plaice (*Pleuronectes platessa*, Linn.).

		Eggs Collected.	Fry Set Free.		
March	14	30,000	26,000	March	30
,,	16	40,000	35,000	April	9
,,	19	50,000	44,000	,,	,,
,,	21	60,000	51,500	,,	,,
,,	24	60,000	51,500	,,	,,
,,	26	70,000	62,000	,,	14
,,	28	90,000	79,000	,,	,,
,,	30	85,000	75,000	,,	20
April	2	90,000	79,500	,,	,,
,,	3	95,000	84,500	,,	,,
,,	5	90,000	79,500	,,	26
,,	7	90,000	79,500	,,	,,
,,	9	90,000	79,500	,,	,,
,,	11	90,000	79,500	,,	,,
,,	14	90,000	79,500	May	5
,,	17	85,000	75,000	,,	,,
,,	20	80,000	70,000	,,	,,
,,	23	75,000	66,500	,,	19
,,	26	50,000	44,000	,,	,,
,,	28	40,000	34,500	,,	,,
,,	30	30,000	27,000	,,	,,
May	3	20,000	17,500	,,	,,
Total Eggs		1,500,000	1,320,000	Total Fry	

Flounder (*Pleuronectes flesus*, Linn.).

		Eggs Collected.	Fry Set Free.		
March	14	... 200,000	177,000	... March	30
,,	16	... 250,000	223,000	... ,,	,,
,,	19	... 300,000	266,000	... ,,	,,
,,	21	... 300,000	266,000	... April	9
,,	24	... 350,000	310,000	... ,,	,,
,,	26	... 450,000	400,000	... ,,	,,
,,	28	... 500,000	445,000	... ,,	,,
,,	30	... 650,000	580,000	... ,,	14
April	2	... 750,000	667,000	... ,,	,,
,,	3	... 750,000	669,000	... ,,	,,
,,	5	... 850,000	757,000	... ,,	20
,,	7	.. 950,000	846,000	... ,,	,,
,,	9	... 1,000,000	887,000	... ,,	,,
,,	11	... 950,000	847,000	... ,,	,,
,,	14	... 900,000	800,000	... ,,	26
,,	17	... 900,000	800,000	... ,,	,,
,,	20	... 800,000	712,000	... May	5
,,	23	... 750,000	669,000	... ,,	,,
,,	26	... 600,000	530,000	... ,,	,,
,,	28	... 600,000	532,000	... ,,	19
,,	30	... 500,000	445,000	... ,,	,,
May	3	... 300,000	266,000	... ,,	,,
,,	5	... 200,000	178,000	... ,,	,,
,,	7	... 200,000	178,000	... ,,	,,
Total Eggs		14,000,000	12,450,000	Total Fry.	

Total Number of Eggs 15,500,000

Total Number of Fry 13,770,000

CLASSES, VISITORS, &c., AT PIEL.

By Andrew Scott.

Four classes for fishermen were held in the spring of 1906. The Education Committee of the Lancashire County Council voted a sum of money for forty-five studentships open to fishermen in the administrative County of Lancaster. The Blackpool Education Committee sent three men, Southport Education Committee two men, Liverpool Education Committee two men, and the Cheshire Education Committee four men. The studentship holders were divided into four classes, three of fifteen each and one of eleven men, as shown by the following lists:—

1st class, held March 12th to 23rd.—J. G. Constable, Askam; R. Parker, Flookburgh; Percy Baxter, Morecambe; G. Parkinson, Morecambe; T. Woodhouse, Morecambe; W. Wilson, Morecambe; R. Abram, Fleetwood; W. Ball, Fleetwood; T. Rawlinson, Fleetwood; Wm. Wright, Fleetwood; J. Abram, Banks; J. Johnstone (Bunger), Banks; J. Barrow, Blackpool; F. Parr, Blackpool; E. Salthouse, Blackpool.

2nd class, held March 26th to April 6th.—S. Mott, Bardsea; W. Benson, Flookburgh; R. Gardner, Morecambe; T. Gerrard, Morecambe; R. Ellwood, Morecambe; J. Wilson, Bolton-le-Sands; T. Smith, Overton; J. T. Bagot, Knott End; R. Ball, Fleetwood; J. Leadbetter, Fleetwood; W. Sharpe, Fleetwood; R. Gillett, Lytham; W. G. Parkinson, Lytham; P. Brookfield, Banks; J. Aughton, Banks.

3rd class, held April 23rd to May 4th.—T. Edmondson, Roosebeck; J. Gardner, Ulverston; J. Procter, Ulverston; J. Wilkinson, Baicliff; T. Westworth,

Flookburgh; W. Bird, Fleetwood; R. Wright, Fleetwood; R. Wilson, Fleetwood; J. R. Croft, Preesall; R. Swarbrick, Hambleton; W. Hadwen, Morecambe; T. Shaw, Morecambe; T. Mayor, Morecambe; R. Abram, Banks; J. Peet, Banks.

4th class, held May 7th to 18th.—J. Bird, Ulverston; R. Stephenson, Heysham; W. Baxter, Banks; J. Lloyd, Marshside; W. Ball, Southport; W. H. Hosier, Liverpool; W. Whelan, Liverpool; T. Bushell, Parkgate; T. Matthews, Parkgate; J. Murray, Liscard; W. Bedson, New Brighton.

The usual votes of thanks to the Sea Fisheries Committee and to the Education Committee were proposed and carried by the fishermen.

The classes for fishermen are now registered by the Board of Education as evening classes, and each of the above classes was inspected by Mr. M. A. Fenton, one of the Government Inspectors. Mr. Fenton's report was as follows:—

> "Demonstrations from the blackboard and abun-
> "dant individual instruction constitute the teaching
> "referred to. The men manipulate admirably, and
> "seem to apply themselves so as to receive as much
> "attention as is to be obtained in their fortnight."

A class in Nature Study for school teachers was held on two week nights and the Saturday afternoons during the period covered by the third and fourth classes for fishermen. This class was organised by the Barrow Education Committee, and was attended by eighteen teachers belonging to their schools. The teachers' class is also recognised by the Board of Education, and registered as an evening school. The following is a copy of the report on the class which was sent to the Barrow Education Committee:—

"Board of Education, South Kensington.
"Barrow-in-Furness, Piel, Marine Laboratory, Teachers'
"Classes, School No. 32,519.

"Report of H.M. Inspector for the year 1905-06, with "remarks, if any, added by the Board of Education:—

"'This is a very useful class. The teaching is "'efficient and thorough, and much interest is "'evinced by the students in the study of the "'marine forms of the syllabus.

"'The work is conducted in a well-equipped "'Laboratory.'"

The members of the Scientific and General Purposes Committees of the Fisheries Committee and members of various Education Committees in the County visited the laboratory, under the leadership of Mr. James Fletcher, while the fishermen's classes were being conducted.

The library has received a number of valuable additions during the year, the most important being:—

A set of fifty-eight volumes, published by the Ray Society, containing amongst others the Monographs by Alder & Hancock, Allman, McIntosh, Bowerbank, Brady, Darwin, &c.

United States Bulletins of the Fish Commission, 1884-1904. 12 vols.

British Fresh-water Fishes, Houghton. 2 vols.

Catalogue of Madreporia, vols. 1-5; presented by the British Museum.

Monograph on the Isopods of North America.

A number of books and pamphlets belonging to the late R. L. Ascroft; presented by Mrs. Ascroft.

A number of reprints of papers from the Reports on the Sea and Inland Fisheries of Ireland, 1904-1905; presented by Mr. E. W. L. Holt, Scientific Adviser.

REPORT ON THE TOW-NETTINGS.

By Andrew Scott.

The collections of pelagic organisms taken by tow-net in various parts of the Irish Sea in 1906 number four hundred. The results from the examination of the material are given in the monthly tables (see below). Although the tables represent the organisms that were present from month to month in particular areas, it does not necessarily follow that they were always in evidence every time a collection was made. Again, the number of records for any station depends largely on the frequency of the fishing. A comparison of the tables given in last year's Report shows that Cardigan Bay had a greater variety of free swimming animals than any other area. The number of tow-nettings taken there represented more than one every week, and practically amounted to five each month. The area is a large one, and collections were made in the vicinity of New Quay and Pwllheli by the fishery officers stationed at these places. Then at intervals the fisheries steamer took tow-nettings in various parts of the territorial waters of the bay. This area, therefore, was fairly well investigated in 1906, and the results were naturally high. Another thing to be remembered is that distribution is rarely uniform. Some organisms may be extremely abundant at one spot, and yet at another, perhaps only a few miles away, are conspicuous by their absence.

During the year 1906, we derived a good deal of fresh information from the tow-nettings relating to the occurrence of various important organisms. Owing to various

circumstances, it is almost impossible to get a complete series of collections for a whole year. A continuous daily, or even weekly, sample from one particular region is apt to be interrupted through conditions of weather and other unforeseen agencies, over which there is no control. Again, a gathering taken once a day, once a week, or once a month, may yield some interesting organisms, but one would like to know what had happened in the interval, whether the organism was only a solitary example or part of a rich, widely-diffused shoal. The only area that is represented at least once every month, in 1906, is Cardigan Bay. This division was dealt with in the last Report, and further consideration of its monthly plankton is, therefore, deferred in the meantime. If the tables giving the occurrence of organisms in the areas investigated be compared, it will be noticed that during July, August and September Port Erin had a greater number of organisms than the other stations during that period. This is entirely due to the way the area was investigated and the large number of samples collected. Professor Herdman chartered the small steam yacht "Madge," and spent his summer vacation making plankton hauls in the open sea, in the vicinity of Port Erin. The region investigated lay mainly between Bradda Head and the Calf Island. The amount of work that was done can be readily understood when it is stated that on the twenty-nine working days when the "Madge" was at work seventy-three tow-nettings in all were taken. Even after the observations made from the yacht ended, other tow-nettings were taken both inside and outside Port Erin Bay by Professor Herdman and Mr. Chadwick. The result is that during the period, July 22nd to September 30th, seventy-nine collections were made. More than half that number were taken in the latter month. With such a large amount of material

to investigate, one would expect that there would be more variety in the plankton than if only one or two samples had been taken in the period. This is the case. In September no less than fifty-eight different kinds of organisms fall to be recorded. Professor Herdman, in his work on the "Madge," used five different kinds of nets, all made of fine silk bolting cloth, as follows:—

A Hensen-Petersen closing net, with 200 meshes to the inch.

A small Apstein net, with 212 meshes to the inch.

An ordinary tow-net, weighted to work below the surface, 120 meshes to the inch.

An ordinary surface net, 120 meshes to the inch, used for the first time.

An ordinary surface net, 120 meshes to the inch, that had been in use for a year.

The five nets were not often used simultaneously, as a rule only the surface and deep-water nets were worked at the same time. On measuring and examining the material collected, it was found that, although the gatherings were taken in equal periods of time in a very limited sea area, there was no strict uniformity, either in quantity or kind of organisms captured. Sometimes the surface net contained more material than the deep one, at other times there was more in the deep net than in the surface one. The old surface net appeared to fish better than the new one. The Apstein net invariably had a smaller catch than the ordinary net. When we find such differences in a small section of the Irish Sea, what must be the conditions when the whole area is fully investigated?

It is proposed, in this Report, to deal with the distribution of organisms, and to show that differences in the nature of the plankton are more frequently than

otherwise co-extensive with the area over which the operations are conducted. It is a well-known fact that land animals and plants have a distribution which depends largely on the physical conditions of their surroundings. One is apt to forget, however, that the same holds good regarding marine life. The sea may appear limitless in extent, but, after all, there are many animals and plants in it that are just as nicely adjusted to their habitat as their relations on land, and any change that takes place in their surroundings has some effect, one way or another, on the inhabitants of the sea. We know far more regarding the inhabitants of the land solely because of the comparative ease in reaching them, compared with the difficulties that lie before the marine investigator. The worker amongst land animals and plants can now afford time to deal with variation in structure, &c., but the marine student has not, by any means, exhausted the vast storehouse of the deep of all its novelties. It is only within comparatively recent years that a wide-spread study of marine life has been undertaken. The co-operation of the Governments of various countries and Sea-Fisheries Authorities, along with the efforts put forth by independent naturalists, has done much to stimulate marine research. The result is, we know a great deal more regarding the distribution of certain classes of pelagic and semi-pelagic organisms now than we did a few years ago. Every scientific expedition throws fresh light on the subject. There are still quite a number of organisms whose present distribution is very limited, but whether they will prove on further investigation to be so local is doubtful. Many new forms of Copepoda were brought to light by the investigations conducted on the "Challenger" over thirty years ago. Some of them were found in tropical seas, and might have been looked

upon still as true warm-water species, but quite lately one or two of these species have been detected off the Coast of Norway and in the deep cold area of the Faröe Channel. Pelagic forms of Copepoda are probably more widely distributed than might be expected. When one, however, finds such a typical littoral form as *Phyllothalestris mysis* (first described by Claus, from the Mediterranean) having its distribution afterwards extended to Norway and Ceylon, or a more inert species like *Laophontodes bicornis* (described from specimens found off the Isle of Man) extending to Cape Verde Islands, there can be little surprise at the occurrence of pelagic forms in unexpected places. In the ordinary course of events, true littoral Copepods are rarely taken in tow-nets, unless these are worked near the bottom. Other means have to be employed for their capture, such as dredging and washing debris from larger invertebrata. It is obvious that it cannot be accurate to state that littoral forms of any kind are absent if the proper methods for collecting them are omitted. A handful of weed washed in weak spirit often brings to light a surprising number of organisms, such as Foraminifera, Ostracoda and littoral Copepoda, that would not be obtained any other way. Two instances of that kind have come under my own notice. One was the washings from a handful of algæ, hurriedly gathered on the shore of the Island of Sokotra, which contained a number of interesting Amphipoda and Isopoda. The other was a small quantity of calcareous and other algæ collected on the dead coral reef flats and madrepora reefs in the Conflict atoll, off the Coast of British New Guinea. When carefully washed and examined, these debris yielded a large number of littoral Copepoda and Ostracoda. Some of the littoral Copepoda from this distant island appear to be

identical with forms we occasionally find in the Irish Sea.

Quite a number of samples of surface plankton have been taken in limited areas of the Irish Sea *on the same day* by the steamer, the Fishery officers, Professor Herdman, and Mr. Chadwick in the course of this year. The results are given on the following pages. Except where otherwise mentioned, the collections were secured with an ordinary open tow-net worked close to the surface.

On January 3rd, a collection was taken off Blackpool and another near the Liverpool Bar Lightship. These places are about forty miles apart. The following are the organisms found* in each :—

	Blackpool.		Liverpool Bar.
Rhizosolenia semispina	c.	...	r.
Rhizosolenia shrubsolei	r.	...	r.
Ceratium tripos	fr.	...	—
Ceratium fusus	fr.	...	r.
Noctiluca	fr.	...	—
Sagitta	ab.	...	c.
Copepoda	ab.	...	r.
Temora	c.	...	—
Acartia clausi..........................	c.	...	r.
Paracalanus	c.	...	r.
Oithona similis	c.	...	—
Oithona nana	r.	...	—
Centropages hamatus	r.	...	—
Pseudocalanus	r.	...	r.

The difference here is very marked, thirteen organisms occurring at Blackpool and only seven at Liverpool Bar. Three out of the seven species of Copepods are absent at the latter place. Samples taken more in the open sea on the following day near the Liverpool North-west Lightship and in Red Wharf Bay—places about forty-five miles apart—gave the following result :—

* ab. abundant ; c. common ; fr. frequent ; r. rare ; v.ab. very abundant.

	N.W. Light Ship.		Red Wharf Bay.
Coscinodiscus concinnus	fr.	...	—
Biddulphia mobiliensis	r.	...	—
Ceratium tripos	r.	...	—
Noctiluca	r.	...	fr.
Pleurobrachia	1	...	—
Autolytus	1	...	fr.
Sagitta	r.	...	ab.
Tomopteris	—	...	r.
Podon	r.	...	—
Hyperia galba	2	...	—
Parathemisto oblivia	2	...	—
Copepoda	ab.	...	c.
Calanus	r.	...	r.
Temora	fr.	...	fr.
Centropages hamatus	r.	...	—
Paracalanus	—	...	r.
Acartia clausi	v. ab.	...	fr.
Oithona similis	fr.	...	—
Oikopleura	r.	...	—

The differences between these two collections are quite as marked as in the previous examples. There was, evidently, a more abundant supply of life out in the open sea than near the land, and it will be noticed that diatoms were absent from territorial waters. There was a great difference in the amount of Copepoda in the two areas. *Acartia clausi* was present in immense numbers offshore, while in Red Wharf Bay the number of this particular species was considerably reduced.

On January 22nd one tow-netting was taken in Port Erin Bay, on the following day two were taken in Cardigan Bay by the steamer, and one by Capt. Jones in Carnarvon Bay. The tow-netting from Port Erin is not strictly comparable with the others, but is given to show the difference between the plankton from the Central area on one day, and that from close inshore in the Southern area on the next day.

	Port Erin.	Near Patches Buoy.	Off Llanon.	Carnarvon Bay.
Biddulphia	ab.	r.	—	—
Chætoceros	ab.	—	—	—
Coscinodiscus	ab.	—	—	—
Rhizosolenia	r.	—	—	—
Acanthometra	r.	—	—	—
Ceratium tripos	fr.	fr.	—	—
Ceratium fusus	fr.	—	—	—
Sagitta	fr.	fr.	—	r.
Tomopteris	fr.	fr.	—	—
Autolytus	—	r.	—	r.
Mitraria	r.	fr.	—	—
Copepoda	c.	c.	—	ab.
Calanus	r.	—	—	—
Pseudocalanus	fr.	fr.	—	ab.
Paracalanus	fr.	fr.	—	c.
Temora	—	fr.	—	c.
Anomalocera	—	—	—	—
Centropages hamatus	—	r.	—	—
Acartia	c.	c.	—	—
Oithona	fr.	—	—	—
Euterpina	r.	—	—	—
Oikopleura	fr.	—	—	—
Plaice eggs	—	4	4	—
Post-larval Herring	—	ab.	—	—

The plankton of Port Erin was very rich in Diatoms, and most of the other organisms mentioned were well represented. The inshore waters of the Southern area possessed quite a different plankton on the following day. Diatoms, with the exception of a few *Biddulphia* taken near the Patches Buoy, were absent, both in Cardigan and Carnarvon Bays. The Copepoda at the Patches Buoy were about as numerous as at Port Erin, but there was a slight difference in the species at the two places. Carnarvon Bay, again, was distinct from any of the other three, and had a very rich supply of Copepoda, but little else. The collection taken off Llanon was rather remarkable, as it only contained four plaice eggs.

Tow-nettings taken in any area at intervals frequently show great changes in the pelagic organisms. This is illustrated in the two tables now given, which show the result from a gathering near the Liverpool N.W. Lightship and one in Red Wharf Bay, on January 31st.

	N.W. Light Ship.		Red Wharf Bay.
Biddulphia	—	...	fr.
Pleurobrachia	r.	...	—
Sagitta	c.	...	ab.
Autolytus	1	...	—
Mitraria	r.	...	—
Crab zoea	r.	...	—
Copepoda	c.	...	v. ab.
Calanus	fr.	...	c.
Pseudocalanus	fr.	...	c.
Paracalanus	fr.	...	c.
Temora	fr.	...	c.
Acartia clausi	c.	...	c.
Oithona similis	—	...	c.
Plaice eggs	1	...	—

When these results are compared with those given for January 4th, it will be seen that Diatoms and Copepods were then fairly abundant in the open sea off the Lightship, but in Red Wharf Bay the former were absent altogether and Copepoda much scarcer. In the above examples a complete reversal is shown to have taken place in the course of twenty-seven days. Diatoms are absent from the open sea collection, and Copepoda much reduced in quantity. On the other hand, Diatoms have come into Red Wharf Bay, and Copepoda become very abundant. Such marked changes are often found, not only after intervals of time, but frequently in a very limited area, on the same day. On February 1st, four tow-nettings were taken along the coast of North Wales, between Red Wharf Bay and Rhyl, which show that

although organisms may be widely distributed the relative abundance may change. The distance between Red Wharf Bay and Rhyl is about fifteen miles, and the following tables show the distribution:—

	Red Wharf Bay.	Off Puffin Island.	Conway Bay.	Off Rhyl.
Biddulphia	r.	—	—	r.
Coscinodiscus	r.	fr.	fr.	r.
Ceratium tripos	r.	—	—	r.
Pleurobrachia	—	r.	r.	r.
Sagitta	r.	v. ab.	v. ab.	r.
Autolytus	r.	—	—	r.
"Mitraria"	r.	—	—	—
Copepoda	c.	c.	c.	c.
Calanus	—	—	r.	—
Pseudocalanus	fr.	fr.	fr.	fr.
Paracalanus	fr.	fr.	fr.	fr.
Temora	fr.	fr.	fr.	fr.
Acartia clausi	fr.	fr.	fr.	fr.
Oithona similis	r.	r.	r.	r.
Euterpina	r.	r.	r.	r.
Plaice eggs	—	1	—	—

The collections taken in Red Wharf Bay and off Rhyl show that the plankton was practically the same at the two places. The intermediate stations, however, show important differences. At the extreme ends of this area Diatoms were rare, and only two genera were represented; *Sagitta* was also scarce. The plankton in the vicinity of Puffin Island and in Conway Bay contained one of the two genera of Diatoms only, but the increase in the number of specimens was quite conspicuous. *Sagitta*, on the other hand, constituted the bulk of the intermediate gatherings, and it is probable that a shoal had been passed through during these observations. This shoal appeared to be quite limited in width and depth, as

only a few specimens were captured by the bottom tow-nets. It will be noticed, too, that only one plaice egg was taken along this fifteen mile line.

The conditions prevailing in the open sea, off the North-East end of the Isle of Man, about the middle of February, are shown by the following three collections, taken in the vicinity of Bahama Bank on February 20th :—

	(1)		(2)		(3)
Sagitta	ab.	...	c.	...	ab.
Tomopteris	—	...	—	...	r.
Autolytus	—	...	r.	...	r.
Copepoda	c.	...	c.	...	c.
Calanus	fr.	...	fr.	...	fr.
Pseudocalanus	ab.	...	ab.	...	ab.
Paracalanus	fr.	...	fr.	...	fr.
Centropages	r.	...	r.	...	r.
Acartia	r.	...	r.	...	r.
Crab zoea	—	...	—	...	r.
Eurydice	—	...	—	...	1
Hyperia	—	...	—	...	1
Mysis	—	...	—	...	1
Nyctiphanes	—	...	—	...	1
Plaice eggs	ab.	...	ab.	...	fr.
Flounder eggs	r.	...	r.	...	r.

The differences in these are very slight, and show that the distribution was fairly uniform. The presence of the higher crustacea in the third haul, the reduction in quantity of *Sagitta* in the second haul, and the decrease in plaice eggs in the third haul are the only important features.

On February 21st one tow-netting was taken in Red Wharf Bay and one in the open sea about twelve miles North-East from the bay. Considerable change in the collections is shown in the following list of organisms :—

	Red Wharf Bay.		12 Miles N.E.
Biddulphia	c.	...	ab.
Coscinodiscus	fr.	...	ab.
Ceratium fusus	—	...	r.
Sagitta	—	...	6
Autolytus	—	...	2
Copepoda	r.	...	r.
Calanus	r.	...	r.
Paracalanus	r.	...	r.
Acartia	r.	...	r.
Oithona	r.	...	r.
Plaice eggs	—	...	r.
Cod eggs	r.	...	—
Haddock eggs	r.	...	—
Bib eggs	—	...	r.
Rockling eggs	r.	...	—

The open sea contained more Diatoms than the territorial waters. A few *Sagitta* and *Autolytus* were present in the open sea, but entirely absent inshore. The eggs of plaice and bib were taken in the open sea only, and those of cod, haddock and rockling inshore.

Two collections taken six miles apart in the area, sixteen miles W.N.W. of Piel, gave practically equal results on March 13th, but the constituents of the plankton were very different from what prevailed in the open sea off Red Wharf Bay two weeks before.

	(1)		(2)
Sagitta	r.	...	r.
Autolytus	—	...	r.
Copepoda	r.	...	r.
Acartia	r.	...	r.
Paracalanus	r.	...	r.
Plaice eggs	ab.	...	ab.
Flounder eggs	ab.	...	ab.
Dab eggs	ab.	...	ab.
Cod eggs	ab.	...	ab.

On March 20th tow-nettings were taken in territorial waters off New Quay Head, in Carnarvon Bay, near Duddon Buoy, and in the open sea fifteen miles West from the entrance to the Duddon. These throw light on the conditions in the territorial waters at the extreme limits of the district, and also enable a comparison to be made between the open sea and inshore waters at the North end of the area.

	Off New Quay.	Carnarvon Bay.	Duddon Buoy.	15 Miles W. from Duddon
Coscinodiscus	—	r.	—	—
Biddulphia	—	r.	—	—
Sagitta	—	r.	r.	r.
Autolytus	r.	r.	—	—
Crab zoea	c.	—	r.	r.
Nauplii of barnacles	c.	v. ab.	—	—
Ostracod stage of barnacles	—	r.	—	—
Copepoda	r.	r.	r.	r.
Calanus	—	—	r.	r.
Paracalanus	—	—	r.	r.
Temora	—	r.	r.	r.
Acartia	r.	r.	r.	r.
Plaice eggs	r.	—	r.	r.
Flounder eggs	—	—	r.	r.
Cod eggs	—	—	r.	r.
Whiting eggs	ab.	r.	r.	r.
Bib	ab.	—	r.	r.
Rockling	ab.	r.	r.	r.

Diatoms and barnacle larvæ were present in Carnarvon Bay only. Copepoda were very scarce at all the stations, but a noticeable difference in variety of species is obvious at the northern area. The eggs of whiting and rockling occurred in all the four collections, but were more numerous off New Quay than in the others. Plaice and bib were present at the North and South extremities, cod and flounder at the North end only. The open sea plankton was the same as that found inshore.

Two collections were taken near Duddon Buoy on March 31st, within three miles of each other, and although they gave similar results so far as variety of the constituents go, showed great difference in relative abundance of Diatoms and *Sagitta*.

	Duddon Buoy.		3 Miles N.W. from the Buoy.
Biddulphia	v. ab.	...	c.
Chætoceros	r.	...	r.
Coscinodiscus	v. ab.	...	c.
Rhizosolenia	r.	...	r.
Ceratium tripos........................	fr.	...	r.
Ceratium fusus	fr.	...	r.
Alcyonium eggs	r.	...	r.
Sagitta	r.	...	v. ab.
Eurydice	r.	...	r.
Copepoda	c.	...	c.
Pseudocalanus	fr.	...	fr.
Paracalanus	fr.	...	fr.
Temora	r.	...	r.
Acartia	fr.	...	fr.
Plaice eggs	r.	...	—
Bib eggs	r.	...	r.

It will be seen that there was a greater abundance of Diatoms, chiefly *Biddulphia* and *Coscinodiscus*, near the buoy than further off, and also that *Sagitta* were more plentiful three miles away from the buoy than close to it. A comparison of these two collections with the one taken close to Duddon Buoy on March 20th, shows a very marked change. Eleven days before these later ones were secured no Diatoms at all were present, and yet, in the course of a short period, they have made their appearance in large numbers.

On April 24th three tow-nettings were taken near the Morecambe Bay Lightship, within an area of about six miles. The results are almost identical, and it is evident

that the constituents were fairly uniformly diffused at this place at the time the samples were taken.

	(1)		(2)		(3)
Biddulphia	ab.	...	ab.	...	ab.
Coscinodiscus	ab.	...	ab.	...	ab.
Rhizosolenia	ab.	...	ab.	...	ab.
Ceratium tripos	c.	...	c.	...	c.
Ceratium fusus	c.	...	c.	...	c.
Alcyonium eggs	r.	...	r.	...	r.
Sagitta	—	...	—	...	r.
Autolytus	r.	...	r.	...	r.
Crab zoea	r.	...	r.	...	c.
Copepoda	r.	...	r.	...	c.
Temora	r.	...	r.	...	c.
Paracalanus	r.	...	r.	...	r.
Acartia	r.	...	r.	...	c.
Ascidian eggs	c.	...	c.	...	c.
Oikopleura	r.	...	r.	...	r.
Dab eggs	v.ab.	...	v.ab.	...	v.ab.
Haddock eggs	v.ab.	...	v.ab.	...	v.ab.
Whiting eggs	v.ab.	...	v.ab.	...	v.ab.
Bib eggs	v.ab.	...	v.ab.	...	v.ab.

Collections taken at the North end of Cardigan Bay, on April 27th, show considerable variation in the constituents of the plankton, as will be seen from the following tables:—

	Tremadoc Bay		Off Llanbedrog.		Off Kilan Head.
Biddulphia	—	...	—	...	r.
Chætoceros	r.	...	—	...	—
Coscinodiscus	ab.	...	—	...	r.
Rhizosolenia	r.	...	—	...	—
Alcyonium eggs	r.	...	—	...	—
Sagitta	r.	...	r.	...	r.
Crab zoea	—	...	r.	...	r.
Nauplii of barnacles	—	...	c.	...	c.
Ostracod stage of barnacles	c.	...	c.	...	c.
Copepoda	c.	...	c.	...	r.
Pseudocalanus	—	...	fr.	...	—
Temora	fr.	...	fr.	...	—
Centropages	fr.	...	fr.	...	—
Acartia	fr.	...	fr.	...	r.
Oithona	r.	...	c.	...	—
Brill eggs	—	...	—	...	r.
Haddock eggs	—	...	—	...	r.
Pollack eggs	—	...	r.	...	—
Sprat eggs	r.	...	r.	...	r.
Rockling eggs	—	...	r.	...	—
Spotted Dragonet eggs	—	...	r.	...	—

Diatoms, especially *Coscinodiscus,* were plentiful in Tremadoc Bay, absent altogether off Llanbedrog, and very scarce off Kilan Head. Copepoda, though common in Tremadoc Bay and off Llanbedrog, were nearly absent at Kilan Head. At the latter place only one species, *Acartia,* was detected. Fish eggs were very unevenly distributed, and out of a total of six different kinds present in the northern portion of Cardigan Bay only one was represented in Tremadoc Bay.

On May 7th, three collections were again taken near Morecambe Bay Lightship. The first were taken close to the ship, the second five miles West, and the third eight miles West from it. The plankton was identical in these samples.

	(1)	(2)	(3)
Biddulphia	r.	r.	r.
Coscinodiscus	r.	r.	r.
Rhizosolenia	v.ab.	v.ab.	v.ab.
Ceratium fusus	c.	c.	c.
Alcyonium eggs	r.	r.	r.
Pleurobrachia	r.	r.	r.
Sagitta	r.	r.	r.
Ostracod stage of barnacles	c.	c.	c.
Copepoda	c.	c.	c.
Pseudocalanus	fr.	fr.	fr.
Temora	fr.	fr.	fr.
Centropages	fr.	fr.	fr.
Acartia	fr.	fr.	fr.
Sprat eggs	r.	r.	r.
Gurnard eggs	—	r.	r.

Although these collections are all practically the same, they show some differences from the former samples taken on April 24th. On the first occasion three genera of Diatoms were present, but all were equally abundant. Thirteen days later two of the genera were exceedingly scarce, while the third, *Rhizosolenia,* had increased in quantity. The complete change in fish eggs is to be

expected. Those noted on the earlier date had probably been hatched, or widely scattered by winds and currents before the second visit. Copepoda had become more plentiful, and the free swimming ostracod stage of barnacles made their appearance amongst the pelagic organisms taken on May 7th.

On May 15th tow-nettings were taken off Blackpool, at the entrances to the Ribble and Mersey, in Carnarvon Bay and off New Quay Head. The differences between the plankton collected off the Lancashire coast and that from the Welsh areas is very marked.

	Off Blackpool.	Ribble entrance.	Mersey entrance.	Carnarvon Bay.	Off New Quay.
Biddulphia	r.	r.	r.	v.ab.	r.
Coscinodiscus	r.	r.	r.	v.ab.	r.
Rhizosolenia	ab.	ab.	ab.	—	—
Ceratium tripos	r.	r.	r.	—	—
Ceratium fusus	r.	—	r.	—	—
Ceratium furca	r.	—	—	—	—
Noctiluca	r.	—	r.	—	—
Pleurobrachia	c.	—	c.	—	—
Sagitta	r.	r.	r.	—	r.
"Mitraria"	r.	—	r.	—	—
Crab zoea	r.	r.	r.	—	—
Ostracod stage of barnacles	—	—	—	c.	—
Copepoda	r.	r.	r.	c.	v.ab.
Paracalanus	r.	r.	r.	—	c.
Temora	—	—	—	c.	c.
Centropages	—	—	—	c.	c.
Anomalocera	—	r.	—	—	fr.
Isias	—	—	—	—	r.
Acartia clausi	r.	r.	r.	—	c.
Acartia discaudata	r.	—	r.	—	—
Evadne	—	r.	r.	—	—
Oikopleura	r.	r.	c.	—	—
Brill eggs	—	—	—	—	r.
Rockling eggs	—	—	—	—	r.

Three genera of Diatoms were represented on the Lancashire coast, but only one of these was plentiful, the

other two were rare. In Carnarvon Bay it was found that the form so abundant between the Mersey entrance and Blackpool was quite absent, but the other two were present in immense numbers. Off New Quay the abundant member of the northern waters was also absent, and the other two rare. The Copepoda were very unequally distributed, large numbers were found off New Quay, a fair quantity in Carnarvon Bay, and only a very few in the North District. Fish eggs were only observed in the collection from New Quay. The distinction between the constituents of the plankton on the Welsh and Lancashire coasts is very marked

The following two results show the conditions existing close to land and in the open sea. On May 22nd one collection was taken off the entrance to the Ribble and one close to the Liverpool North-West Lightship. The latter is about seventeen miles S.W. from the former.

	Ribble Entrance.		Liverpool N.W. Lightship.
Coscinodiscus	r.	...	r.
Rhizosolenia	r.	...	r.
Ceratium tripos	r.	...	r.
Ceratium fusus	r.	...	r.
Pleurobrachia	r.	...	—
"Mitraria"	r.	...	r.
Sagitta	r.	...	r.
Crab zoea	—	...	r.
Crab megalopa	r.	...	—
Podon	—	...	r.
Evadne	r.	...	—
Copepoda	r.	...	c.
Paracalanus	r.	...	r.
Temora	r.	...	c.
Centropages	—	...	c.
Anomalocera	r.	...	—
Acartia	r.	...	c.
Oikopleura	r.	...	r.
Brill eggs	—	...	r.
Rockling eggs	—	...	r.

The most noticeable difference between the two stations is the relative abundance of the Copepoda; these were more numerous in the open sea than close inshore.

The other organisms, with the exception of the fish eggs, appeared to be fairly uniform in their distribution on that date. A comparison of the plankton at the Ribble entrance on the above date with that of seven days previously shows a great change in the quantity of Diatoms on the two dates. On the first date three genera were represented, one of which was present in large numbers on the second visit, one of the forms had disappeared, and the prevalent genus had decreased so very much in quantity that only a few specimens were detected.

On May 24th two tow-nettings were taken in Cardigan Bay, one near the Patches Buoy and the other off New Quay Head, about fourteen miles S.W. from the former. A third collection was made off Dinas Head, about twenty-three miles in a westerly direction from New Quay Head. These three were all from inside the territorial limit, and give an idea of the conditions of the plankton along that portion of the Welsh coast.

	Patches Buoy.	New Quay Head.	Dinas Head.
Pleurobrachia	c.	—	r.
Sarsia tubulosa	—	—	c.
Sagitta	r.	c.	c.
Autolytus	r.	—	r.
"Mitraria"	r.	r.	—
Podon	—	r.	—
Crab zoea	—	r.	c.
Megalopa	—	—	c.
Copepoda	ab.	ab.	c.
Calanus	—	—	r.
Pseudocalanus	c.	c.	fr.
Paracalanus	c.	c.	fr.
Temora	c.	c.	fr.
Centropages	c.	c.	fr.
Oikopleura	—	r.	—
Brill eggs	r.	r.	—
Turbot eggs	—	r.	—
Gurnard eggs	r.	—	r.
Sprat eggs	—	r.	—
Rockling eggs	—	—	r.

The distribution of the organisms in this area was evidently far from uniform. The Copepoda in the first

two were practically identical, and they were more abundant there than off Dinas Head. On the other hand, Crab Zoea and Megalopa, though tolerably common off Dinas Head, were quite absent at the Patches Buoy. Four out of the five kinds of fish eggs occurred off New Quay, and two only at the other places.

Three weeks later, June 14th, the same area was again traversed, and the following are the results then obtained:—

	Patches Buoy.	New Quay Head.	Dinas Head.
Pleurobrachia	—	r.	c.
Sagitta	r.	—	c.
Autolytus	r.	r.	—
"Mitraria"	r.	—	—
Crab zoea	r.	c.	c.
Crab megalopa	—	r.	r.
Copepoda	ab.	ab.	r.
Calanus	—	—	r.
Pseudocalanus	r.	—	—
Paracalanus	c.	c.	—
Temora	c.	—	r.
Centropages	r.	r.	r.
Acartia	ab.	ab.	—
Oikopleura	—	—	c.
Mackerel eggs	r.	ab.	—
Rockling eggs	c.	c.	—
Weever eggs	—	r.	—
Common Dragonet eggs	—	r.	—

There is very little difference in the plankton of the two periods, excepting a natural change in the kind of fish eggs. Copepoda continued to be abundant at the South end of Cardigan Bay, and scarce off Dinas Head. *Acartia*, which was not seen in the Cardigan Bay collections on May 24th, was extremely plentiful on the second occasion. Crab Zoea were more common off New Quay Head, and had extended to the region of the

Patches Buoy on the second visit. Off New Quay Head the sea was richly populated with the eggs of mackerel.

On July 12th tow-nettings were taken off Puffin Island, in Red Wharf Bay, and off Kilan Head at the North end of Cardigan Bay. The results showed extreme differences:—

	Off Puffin Island.	Red Wharf Bay.	Kilan Head.
Noctiluca	v.ab.	v.ab.	—
Sagitta	r.	—	—
Crab zoea	r.	—	c.
Crab megalopa	r.	—	c.
Evadne	—	—	v.ab.
Copepoda	v.r.	—	v.ab.
Calanus	v.r.	—	c.
Temora	v.r.	—	—
Centropages	v.r.	—	c.
Isias	—	—	fr.
Anomalocera	—	—	fr.
Acartia	v.r.	—	v.ab.
Brill eggs	—	—	r.
Sprat eggs	—	—	r.
Weever eggs	—	—	r.
Rockling eggs	—	—	r.

The plankton in Red Wharf Bay consisted of *Noctiluca* only. Off Puffin, the chief constituent was again *Noctiluca*. The other organisms mentioned were represented by a few individuals. The collection taken off Kilan Head gave quite different results. The plankton there, at that time, was practically composed of *Evadne* and *Acartia* in great abundance. *Calanus*, *Centropages* and larvæ of crabs were tolerably common.

Collections off Blackpool and at the entrance to the Ribble were taken on July 18th. These stations are only about six miles apart, yet the plankton was very distinct in each place.

	Off Blackpool.		Entrance to Ribble.
Ceratium tripos	c.	...	r.
Noctiluca	c.	...	r.
Sagitta	—	...	r.
Crab zoea	c.	...	v.ab.
Crab megalopa	r.	...	v.ab.
Copepoda	v.r.	...	r.
Centropages	v.r.	...	r.
Temora	v.r.	...	r.
Anomalocera	v.r.	...	r.
Acartia	—	...	r.
Oikopleura	—	...	r.

Noctiluca, though tolerably common off Blackpool, was almost absent a few miles away. On the other hand, the collection taken at the entrance to the Ribble consisted of little else than Zoea and Megalopa of crabs. Off Blackpool the former was fairly numerous, and the latter very scarce.

The North Wales area was traversed again on August 10th, and tow-nettings were taken in Llandudno Bay, off Puffin Island and in Red Wharf Bay. These collections differed from each other, and also showed great changes when compared with the plankton found four weeks previously.

	Llandudno Bay.		Off Puffin Island.		Red Wharf Bay.
Rhizosolenia	—	...	—	...	r.
Ceratium tripos	—	...	r.	...	r.
Noctiluca	v.ab.	...	—	...	v.ab.
Pleurobrachia	—	...	—	...	r.
Sagitta	r.	...	—	...	—
Crab zoea	—	...	c.	...	—
Crab megalopa	r.	...	—	...	r.
Copepoda	—	...	r.	...	r.
Temora	—	...	r.	...	r.
Centropages	—	...	r.	...	r.
Acartia	—	...	r.	...	r.
Oikopleura	—	...	—	...	r.
Weever eggs	—	...	—	...	r.

The plankton in Llandudno Bay was practically composed of *Noctiluca.* In Red Wharf Bay similar conditions prevailed, but the *Noctiluca* was mixed with a few other organisms. It will be noted, too, that *Rhizosolenia* was apparently just making its appearance.

The intermediate plankton in the vicinity of Puffin Island was quite distinct from that found at the ends of the area. There was no *Noctiluca* at all, but Crab Zoea were tolerably common. Comparing these results with the condition existing a month before, we find that the sea close to Puffin Island was then swarming with *Noctiluca*, and that Crab Zoeæ were very scarce. In Red Wharf Bay we had only pure *Noctiluca* at the beginning of August, now other organisms are making their appearance.

After the lapse of another month the area was partly investigated again, and at the same time a sample of the plankton in the Central area was secured. Collections were taken on September 7th in Llandudno, Conway and Red Wharf Bays, and in the vicinity of Port Erin. The following are results:—

	Llandudno Bay.	Conway Bay.	Red Wharf Bay.	Port Erin.
Biddulphia	—	—	r.	—
Chætoceros	—	—	r.	—
Rhizosolenia	—	—	ab.	—
Ceratium tripos	c.	c.	c.	c.
Ceratium fusus	—	—	r.	—
Noctiluca	c.	c.	c.	—
Pleurobrachia	c.	—	c.	—
Sagitta	c.	c.	c.	c.
Autolytus	—	—	—	r.
Tomopteris	—	—	r.	—
Crab zoea	—	c.	—	c.
Crab megalopa	—	c.	c.	—
Podon	—	—	—	c.
Evadne	—	—	—	c.
Copepoda	c.	c.	c.	ab.
Calanus	—	—	—	c.
Pseudocalanus	—	—	—	c.
Paracalanus	fr.	fr.	fr.	c.
Anomalocera	—	—	—	c.
Temora	fr.	—	—	c.
Centropages	fr.	fr.	fr.	r.
Isias	—	—	—	r.
Acartia	c.	c.	c.	c.
Oithona	—	—	—	c.
Eurydice	—	—	r.	—
Parathemisto	r.	—	r.	—
Hyperia	r.	—	—	—
Oikopleura	—	—	r.	—

Noctiluca was less abundant, but the Copepoda had become more numerous, since the visit on August 10th. Diatoms appeared to be increasing, and *Rhizosolenia* was extremely plentiful compared with the results obtained a month before in Red Wharf Bay. The sea near Port Erin had a rich supply of Copepods, but no Diatoms were present.

On September 14th one tow-netting was taken in Red Wharf Bay, one at the entrance to the Mersey and one in the vicinity of Port Erin. The results show some differences between the two coastal areas, and a very great distinction between the plankton of the coast and that of the Central area.

	Red Wharf Bay.	Entrance to Mersey.	Port Erin.
Rhizosolenia	r.	—	—
Ceratium tripos	c.	c.	c.
Ceratium fusus	r.	r.	—
Noctiluca	c.	c.	—
Pleurobrachia	c.	—	—
Sagitta	c.	r.	r.
Autolytus	—	—	r.
Mitraria	r.	—	—
Crab zoea	—	r.	r.
Crab megalopa	c.	r.	—
Evadne	—	—	c.
Podon	—	—	c.
Copepoda	r.	r.	c.
Calanus	—	—	fr.
Pseudocalanus	—	—	fr.
Paracalanus	—	—	fr.
Temora	r.	r.	fr.
Centropages	r	r.	fr.
Anomalocera	—	—	fr.
Acartia	r.	r.	fr.
Oithona	—	—	fr.
Oikopleura	—	r.	fr.

Considerable change had evidently taken place in Red Wharf Bay in the course of seven days. A week previous to this sample being taken the bay was full of *Rhizosolenia*, with representatives of *Coscinodiscus* and *Biddulphia*. Now we see that the two latter have gone, and the first has become very scarce. Copepoda continued to be very scarce along the coast, but were tolerably common in the Central area.

A partial investigation of the North Wales area was again made on October 25th. One collection was taken off Puffin Island and one in Llandudno Bay. A tow-netting was taken in the vicinity of Port Erin on the same day, so that it is possible to compare the coastal plankton with that in the Central area.

	Off Puffin Island.	Llandudno Bay.	Port Erin.
Biddulphia	—	—	r.
Chætoceros	c.	c.	ab.
Coscinodiscus	ab.	v.ab.	c.
Rhizosolenia	c.	c.	—
Ceratium tripos	c.	c.	r.
Ceratium furca	c.	c.	—
Ceratium fusus	c.	c.	r.
Pleurobrachia	r.	r.	r.
Sagitta	v.ab.	c.	c.
Copepoda	v.ab.	c.	ab.
Calanus	—	—	r.
Pseudocalanus	—	—	fr.
Paracalanus	c.	fr.	fr.
Temora	c.	fr.	fr.
Centropages	c.	fr.	—
Acartia	c.	fr.	c.
Oithona	c.	fr.	fr.
Oikopleura	—	—	fr.

The above tables show that Diatoms had become very numerous in the coastal waters of North Wales, and also that, although they were not uniformly distributed, the

visitation had extended to the Isle of Man. The most abundant form along the North Wales coast was *Coscinodiscus*, while *Chætoceros* was the most conspicuous at Port Erin. *Sagitta* was extremely plentiful off Puffin Island, and tolerably common in Llandudno Bay and at Port Erin. Copepoda had increased in quantity in the coastal area in the course of six weeks, and were also abundant at Port Erin.

On November 1st one collection was made at the entrance to the Ribble and another in Red Wharf Bay. These show that Diatoms were widely distributed in the territorial area.

	Entrance to Ribble.		Red Wharf Bay.
Coscinodiscus	c.	...	c.
Rhizosolenia	r.	...	r.
Ceratium tripos	c.	...	c.
Ceratium fusus	c.	...	—
Noctiluca	c.	...	c.
Sagitta	r.	...	c.
Crab zoea	—	...	r.
Crab megalopa	—	...	r.
Copepoda	c.	...	ab.
Calanus	—	...	r.
Pseudocalanus	—	...	c.
Paracalanus	—	...	ab.
Temora	c.	...	c.
Centropages	c.	...	r.
Oithona	c.	...	c.

Copepoda appeared to be more plentiful in Red Wharf Bay than at the entrance to the Ribble, and there was also a greater variety at the former place. The other constituents of the plankton differed very slightly in the two samples.

Two or more surface tow-nettings taken in the vicinity of Port Erin on the same day also show that the plankton may be almost identical at different spots at one period,

and that variation may be considerable at another date. On successive days one may even find that the quantity and kind of organisms undergo changes more or less marked.

On April 6th one tow-netting was taken in Port Erin Bay and another off the Calf Island. These show a certain amount of similarity.

	Port Erin Bay.		Off Calf Island.
Biddulphia	ab.	...	ab.
Chaetoceros	c.	...	c.
Coscinodiscus	v.ab.	...	v.ab.
Rhizosolenia	—	...	r.
Acanthometra	r.	...	—
Ceratium tripos	r.	...	—
Ceratium fusus	r.	...	—
Sagitta	r.	...	—
"Mitraria"	r.	...	r.
Nauplii of barnacles	c.	...	—
Crab zoea	r.	...	—
Copepoda	c.	...	c.
Pseudocalanus	fr.	...	fr.
Temora	fr.	...	fr.
Centropages	r.	...	r.
Acartia	fr.	...	fr.
Oithona	fr.	...	fr.
Whiting eggs	—	...	r.
Gurnard eggs	r.	...	r.
Sprat eggs	r.	...	r.
Rockling eggs	r.	...	—
Common Dragonet	r.	...	r

Diatoms and Copepoda had a uniform distribution in these areas at this time, but the other organisms mentioned were evidently limited to Port Erin Bay.

A few days later considerable variation was found in the plankton in Port Erin Bay and its immediate neighbourhood. On April 9th one sample was collected

in Port Erin Bay, and another just outside the seaward limit of this bay.

	Port Erin Bay.		Outside Port Erin Bay.
Biddulphia	ab.	...	r.
Chætoceros	c.	...	---
Coscinodiscus	v.ab.	...	r.
Rhizosolenia	r.	...	--
Ceratium tripos	r.	...	---
Ceratium fusus	r.	...	---
Sagitta	r.	...	c
Nauplii of barnacles	r.	...	---
Copepoda	c.	...	ab.
Calanus	—	...	fr.
Pseudocalanus	fr.	...	c.
Temora	fr.	...	c.
Centropages	r.	...	fr.
Acartia	fr.	...	c.
Oithona	fr.	...	fr.
Long Rough Dab eggs	—	...	r.
Solenette eggs	fr.	...	—
Whiting eggs	—	...	r.
Ling eggs	—	...	r.
Sprat eggs	—	...	r.
Rockling eggs	—	...	r.

On this occasion Diatoms were confined practically to Port Erin Bay. Their relative abundance was the same as three days previously, and it will be noticed that a few *Rhizosolenia* were now found. Outside the limits of the bay we find an almost entire absence of Diatoms. One or two *Biddulphia* and *Coscinodiscus* were all that represented this important class of plankton. The Copepoda in the bay appeared to be fairly stationary, but out in the open sea they seemed to be increasing in quantity when compared with the sample taken off the Calf Island a few days before. *Sagitta* had also become tolerably common in the open, but still remained very scarce inside.

On August 24th collections of the open sea and inshore plankton were again taken. The open sea sample was collected three miles West of Bradda Head, and the shore one off Fleshwick. The latter place is about five miles due East from the former.

	3 Miles West of Bradda Head.		Off Fleshwick.
Chætoceros	r.	...	r.
Ceratium tripos	fr.	...	c.
Noctiluca	—	...	r.
Evadne	—	...	r.
Podon	—	...	r.
Crab zoea	r.	...	r.
Crab megalopa	r.	...	—
Copepoda	ab.	...	ab.
Pseudocalanus	—	..	fr.
Paracalanus	c.	...	c.
Temora	—	...	r.
Anomalocera	r.	...	—
Parapontella	r.	...	—
Isias	fr.	...	r.
Acartia	fr.	...	fr.
Oithona	c.	...	c.
Oikopleura	fr.	. .	fr.
Weever eggs	1	. .	—
Quantity of Material	3 c.c.	...	8 c.c.

The most noteworthy difference between these two samples is in the quantity taken. The plankton inshore was evidently more abundant than in the open sea. There was also a slight change in the variety of organisms captured at the two places. Copepoda were just as numerous at the one station as at the other. *Anomalocera* and *Parapontella* were noted in the open sea but not inshore, while *Pseudocalanus* and *Temora* were found inshore only.

Inshore collections were taken on August 28th off Niarbyl and between Peel and Jurby, at a distance of about seven miles apart, and gave the following results:—

	Off Niarbyl.		Between Peel and Jurby.
Chætoceros	fr.	...	c.
Ceratium tripos	fr.	...	c.
Autolytus	c.	...	r.
Crab zoea	r.	...	r.
Crab megalopa	—	...	r.
Podon	r.	...	—
Evadne	r.	...	—
Copepoda	c.	...	c.
Calanus	r.	...	r.
Pseudocalanus	r.	...	—
Paracalanus	r.	...	fr.
Temora	r.	...	—
Centropages	r.	...	r.
Isias	r.	...	—
Acartia	fr.	...	fr.
Oithona	c.	...	c.
Oikopleura	fr.	...	r.
Mackerel eggs	r.	...	—
Rockling eggs	c.	...	r.
Quantity of Material	3 c.c.	...	13 c.c.

These collections again show considerable variation in quantity of plankton at different places on the same day. Diatoms were more numerous off Peel than at Niarbyl, the other organisms also showed corresponding changes in distribution at the two stations.

On September 1st a sample of the plankton in the open sea four miles West of Bradda Head was taken, and also an inshore one off Niarbyl. The latter is about eight miles East-North-East from the former station.

	4 Miles West of Bradda Head.		Off Niarbyl.
Chætoceros	fr.	...	r.
Ceratium tripos	fr.	...	c.
Sagitta	—	...	r.
Autolytus	—	...	r.
Crab zoea	r.	...	c.
Crab megalopa	r.	...	r.
Podon	—	...	c.
Copepoda	r.	...	ab.
Calanus	—	...	fr.
Pseudocalanus	r.	...	r.
Paracalanus	—	...	r.
Centropages	r.	...	fr.
Anomalocera	r.	...	fr.
Labidocera	—	...	r.
Acartia	fr.	...	c.
Oithona	fr.	...	fr.
Oikopleura	fr.	...	c.
Sprat eggs	r.	...	—
Rockling eggs	—	...	r.
Quantity of Material	1 c.c.	...	4 c.c.

It is evident from the above results that the sea contained a more abundant plankton close inshore than in the open, and also that there was a much greater supply of Copepoda off Niarbyl than at the outside station. On comparing these results with previous ones obtained in the same areas, we find that, although there is not much change in quantity between the plankton off Niarbyl on August 28th and September 1st, the relative abundance of its constituents had altered at the later date. On the former date *Chætoceros* was fairly conspicuous and Copepoda only tolerably common. Four days later it will be noted that *Chætoceros* has almost disappeared and Copepoda become abundant. The collections taken West of Bradda Head, besides differing in quantity captured, also show a complete change in the relative abundance. The conditions are just the exact opposite from the

Niarbyl plankton. On August 24th *Chætoceros* was very rare and Copepoda abundant, while on September 1st it was found that *Chætoceros* had become conspicuous and Copepoda scarce.

On September 10th tow-nettings were taken in the open sea, one nine miles West-North-West of Port Erin and another five miles West of Dalby. The latter station is about five miles due East from the former. The following are the results:—

	9 Miles W.N.W. of Port Erin.		5 Miles W. of Dalby.
Chætoceros	r.	...	fr.
Coscinodiscus	r.	...	—
Rhizosolenia	—	...	r.
Ceratium tripos	r.	...	fr.
Sagitta	r.	...	r.
Autolytus	—	...	r.
Podon	—	...	r.
Evadne	—	...	r.
Crab zoea	r.	...	fr.
Crab megalopa	r.	...	fr.
Copedoda	c.	...	ab.
Calanus	fr.	...	fr.
Pseudocalanus	—	...	fr.
Paracalanus	—	...	fr.
Temora	r.	...	—
Centropages	fr.	...	fr.
Anomalocera	fr.	...	fr.
Acartia	r.	...	fr.
Oithona	r.	...	—
Oikopleura	—	...	c.
Sprat eggs	r.	...	—
Quantity of material	0·25 c.c.	...	6 c.c.

The quantity of plankton in the two areas evidently differed very much. One would naturally expect to find that the larger gathering would contain exactly the same kind of organisms that were present in the small catch, especially as the distance that divided the two areas was

comparatively short, had distribution been uniform. We find, however, that four of the constituents of the small catch were absent at a spot five miles away. It is obvious, then, that there was no uniformity in the plankton in these areas on September 10th.

A week later, September 17th, collections were taken eight miles North-West of Port Erin and five miles West of Cronk, which gave the following results:—

	8 Miles N.W. of Port Erin.		5 Miles W. of Cronk.
Biddulphia	r.	...	r.
Chætoceros	—	...	r.
Coscinodiscus	fr.	...	r.
Ceratium tripos	fr.	...	c.
Sagitta	r.	...	—
Autolytus	—	...	r.
Copepoda	r.	...	c.
Centropages	r.	...	r.
Anomalocera	—	...	c.
Acartia	r.	...	r.
Oithona	r.	...	r.
Oikopleura	—	...	fr.
Sprat eggs	—	...	r.
Quantity of material	0·5 c.c.	...	3 c.c.

The difference in the constituents and the quantity of plankton taken are well marked in this instance. The distribution was probably more uniform than on September 10th, as only one of the organisms in the small collection was absent from the larger one. The first station in the above list is about three miles East-North-East of the area, nine miles West-North-West of Port Erin, visited on September 10th. A comparison of the plankton taken at these two places on the dates given shows that considerable changes had taken place in the course of a week. The amount of plankton in the water was about the same on the two dates. On September 10th *Chætoceros* and *Coscinodiscus*

represented the Diatoms; both were scarce. A week later *Chætoceros* was absent, *Coscinodiscus* had become more numerous and *Biddulphia* was found. Copepoda were tolerably plentiful the week previous, and such forms as *Calanus* and *Anomalocera* were quite conspicuous. Six genera were then present. On September 17th the Copepoda had almost disappeared. Only three of the genera observed on the former visit were found, and these were represented by a few individuals.

We sometimes find that the pelagic life of the sea undergoes great changes in a very short time. Organisms that may be abundant one day are often quite absent on the next, and collections taken in the same place on successive days rarely give identical results.

On August 22nd and 23rd the sea North of the Calf Island was investigated, and the following organisms were found:—

	August 22.		August 23.
Chætoceros	r.	...	r.
Crab megalopa	r.	...	—
Copepoda	r.	...	c.
Paracalanus	v.r.	...	—
Temora	v.r.	...	—
Acartia	v.r.	...	—
Oithona	r.	...	c.
Oikopleura	c.	...	—
Quantity of material	2 c.c.	...	1 c.c.

The first visit gave a greater number of organisms than the second. Copepoda, although very scarce on the 22nd, were represented by four genera. Next day this group was tolerably common, yet only one genus was noted.

Collections taken off Niarbyl on August 27th and 28th and September 1st showed differences of various kinds.

	August 27.		August 28.		Sept. 1.
Chætoceros	c.	...	fr.	...	r.
Ceratium tripos	c.	..	fr.	...	c.
Sagitta	—	...	—	...	r.
Autolytus	—	...	r.	...	r.
Crab zoea	—	...	r.	...	c.
Crab megalopa	—	...	—	...	r.
Podon	—	...	c.	...	c.
Evadne	—	...	c.	...	—
Copepoda	v.ab.	...	c.	...	ab.
Calanus	—	...	r.	...	fr.
Pseudocalanus	r.	...	r	...	r.
Paracalanus	fr.	...	r.	...	r.
Temora	r.	...	r	...	fr.
Centropages	r.	...	r.	...	fr.
Anomalocera	r.	...	—	...	fr.
Parapontella	r.	...	r.	...	—
Labidocera	—	...	r.	...	r.
Isias...............................	r.	...	r.	...	—
Acartia	fr.	...	fr.	...	c.
Oithona	c.	...	c.	...	fr.
Oikopleura	fr.	...	fr.	...	c.
Mackerel eggs	—	...	r.	...	—
Rockling eggs	—	...	r.	...	r.
Quantity of material	11 c.c.	...	3 c.c.	...	4 c.c.

On August 27th the pelagic life was far more abundant than at the later dates. The Copepoda varied in genera and relative abundance each visit. *Podon* and *Evadne*, although tolerably common on August 28th were quite absent on the previous day, and only *Podon* was noted on September 1st. *Sagitta* was not found either on August 27th or 28th, but was represented by a few specimens on September 1st. Crab Zoea were found to be tolerably common on September 1st, scarce on August 28th, and entirely absent on the 27th. Megalopa were only noted on September 1st.

Tow-nettings taken at longer intervals in the same spot frequently show extreme variations. This is well

illustrated in the results obtained from collections made in Port Erin Bay on September 25th, 26th, 27th and on October 4th.

	Sept. 25-27.		Oct. 4.
Biddulphia	r.	...	v.r.
Chætoceros	ab.	...	v.r.
Coscinodiscus	r.	...	v.r.
Rhizosolenia	fr.	...	v r.
Ceratium tripos	fr.	...	r.
Pleurobrachia	r.	...	---
Sagitta	c.	...	r.
Copepoda	c.	...	v.ab.
Calanus	r.	...	r
Pseudocalanus	fr.	..	c.
Paracalanus	fr.	...	c.
Temora	fr	...	fr.
Acartia	c.	...	c.
Oithona	fr.	...	c.
Oikopleura	fr.	...	r.
Quantity of Material	25 c.c.	...	12 c.c.

On September 25th the sea water was filled with Diatoms, chiefly *Chætoceros*. *Sagitta* were tolerably common, Copepoda were fairly numerous, the most plentiful being *Acartia*. During the next two days similar conditions prevailed, not only in Port Erin Bay itself, but in all the outer area from Bradda Head to Bay Fine. On October 4th, just a week later, the conditions had completely changed. Diatoms had almost vanished. only a few individuals belonging to the genera mentioned were found. Copepoda had, however, become extremely abundant. *Pseudocalanus*, *Paracalanus*, *Acartia*, and *Oithona* all being tolerably common. The water was less densely populated with organisms on October 4th than between September 25th and 27th.

The table opposite gives the results obtained from the tow-nettings taken in the vicinity of Port Erin from

July 22nd to November 5th, and includes the special work on the s.y. "Madge."

It may be argued that the plankton near the land is more susceptible to sudden changes than that of the open sea; that winds, currents and other agencies have great effect on local distribution; that the further one proceeds away from land influences the results will be found to be more equal. Against this it may be stated that regions where winds and currents have no effect are difficult to find, and one has to make the best of his opportunities. My own experience, from a long dealing with plankton from many regions, is that one very rarely finds exactly the same kinds of organisms or the same relative abundance in collections taken on the same day.

A recent expedition with the Hensen net across the Irish Sea, from Piel Gas Buoy to the Isle of Man, gave very interesting results. On November 13th, starting from Piel Gas Buoy and proceeding in a north-westerly direction to the Isle of Man, four hauls were made. The first haul was taken six miles from the gas buoy, the second fifteen miles, the third twenty-four miles, and the fourth forty-two miles off the buoy. Each of the three last hauls was made nine miles away from the preceding one. The net was lowered to a depth of ten fathoms at each station and then drawn slowly to the surface. The water everywhere was found to be teeming with Diatoms. The first haul contained a great abundance of *Chætoceros* (four species) and *Rhizosolenia*. In the second haul *Coscinodiscus* was the chief constituent. The third haul contained an abundance of *Eucampia* and *Rhizosolenia*. The fourth haul was very similar to the first. Copepoda were comparatively scarce throughout the traverse, and consisted mainly of *Paracalanus* and *Oithona*. The first haul contained one *Calanus* and six *Temora*. *Temora* was

not taken again, and the second and third hauls had no *Calanus*. The fourth haul contained eight *Calanus*. Amongst other things, *Noctiluca* and *Sagitta* were tolerably common in the four hauls.

The cruise was continued to the West side of the Isle of Man. Six miles North from Peel another haul was taken, which showed a complete change in constituents. Three *Sagitta* and sixteen *Calanus* were found. *Pseudocalanus*, *Acartia* and *Oithona* were tolerably common. Four genera of Diatoms, represented in each case by a very few specimens, a few larval Polychætes, *Ceratium tripos* and *C. fusus*, and "*Mitraria*" but no *Noctiluca*, were taken. It is probable that the few Diatoms present in the fifth haul had remained attached to the meshes of the net since the previous haul. A collection taken with an ordinary surface tow-net near the same spot did not contain a single Diatom. Otherwise the constituents found by this net were the same as those contained in the Hensen net collection. The quantity of material taken each time the Hensen net was hauled differed in every instance.

The colour of the material collected in hauls I.-IV. varied from a decided green to a greenish yellow. The first haul, from its characteristic colour was obviously mainly composed of Diatoms. Haul V. was almost white in colour.

The following table shows the results of the five hauls with the Hensen net :—

Results of Five Hauls taken with the Hensen Vertical Net on the same day, November 19th, 1906, in different parts of the Irish Sea.

	6 miles N.W. from Piel Gas Buoy.	15 miles N.W. from Piel Gas Buoy.	24 miles N.W. from Piel Gas Buoy.	32 miles N.W. from Piel Gas Buoy.	6 miles N.W. from Peel, Isle of Man
Quantity in cubic centimetres	4	1	2	2·5	0·5
Asterionella bleakleyi	fr.	r.	r.	fr.	—
Biddulphia mobiliensis	r.	r.	r.	fr.	v.r.
Chætoceros constrictum	c.	fr.	fr.	c.	—
Chætoceros debile	fr.	fr.	fr.	fr.	—
Chætoceros decipiens	c.	fr.	fr.	c.	v.r.
Chætoceros teres	fr.	fr.	fr.	fr.	—
Coscinodiscus concinnus	fr.	ab.	fr.	fr.	v.r.
Ditylium brightwelli	r.	r.	r.	r.	—
Eucampia zoodiacus	c.	fr.	ab.	c.	—
Melosira borreri	c.	fr.	fr.	c.	—
Rhizosolenia semispina	ab.	fr.	ab.	ab.	v.r.
Rhizosolenia shrubsolei	c.	fr.	fr.	c.	—
Ceratium furca	fr.	fr.	fr.	fr.	—
Ceratium fusus	c.	fr.	fr.	fr.	r.
Ceratium tripos	c.	fr.	c.	fr.	r.
Tintinnopsis campanula	r.	—	—	—	—
Noctiluca miliaris	fr.	fr.	fr.	fr.	—
Pleurobrachia pileus	1	—	2	—	—
Sagitta bipunctata	c.	50	c.	c.	3
Larval Polychaeta	r.	r.	r.	r.	r.
"Mitraria"	r.	r.	r.	r.	r.
Calanus helgolandicus	1	—	—	8	16
Pseudocalanus elongatus	r.	fr.	fr.	fr.	fr.
Paracalanus parvus	fr.	c.	c.	fr.	c.
Temora longicornis	6	—	—	—	—
Acartia clausi	r.	r.	fr.	fr.	fr.
Oithona similis	fr.	fr.	fr.	fr.	fr.
Oikopleura	r.	r.	r.	r.	r.
Copepod nauplii	fr.	r.	r.	r.	r.

The following tables show the occurrence from month to month of the various organisms identified in the plankton collected from the areas named in 1906:—

January.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Bahama Bank.	Lune Deep.	Port Erin.	Luce Bay.
Biddulphia mobiliensis			+	+		+							+	
Chætoceros contortum													+	
Chætoceros criophilum													+	
Chætoceros decipiens													+	
Chætoceros teres													+	
Coscinodiscus concinnus		+	+	+									+	
Rhizosolenia semispina	+		+											
Rhizosolenia setigera		+											+	
Rhizosolenia shrubsolei	+		+											
Ceratium fusus	+	+	+	+									+	
Ceratium tripos	+	+	+	+		+							+	
Acanthometra sp.													+	
Noctiluca miliaris	+	+	+	+										
Pleurobrachia pileus		+	+	+		+				+				
Sagitta bipunctata	+	+		+	+	+				+			+	
Autolytus prolifer			+	+	+	+				+				
Tomopteris onisciformis				+		+							+	
Larval Polychæta			+										+	
"Mitraria"						+				+			+	
Crab zoea										+				
Mysis stage of Crangon										+				
Young Mysis				+						+				
Hyperia galba				+										
Parathemisto oblivia				+										
Paramphithöe bicuspis				+										
Iphimedia obesa				+										
Paratylus swammerdamii				+										
Nyctiphanes norvegica				+	+	+				+				
Podon intermedium			+											
Calanus helgolandicus			+			+				+			+	
Pseudocalanus elongatus	+		+	+	+	+				+			+	
Paracalanus parvus	+	+	+	+	+	+				+			+	
Temora longicornis	+		+	+	+	+				+				
Centropages hamatus	+		+	+		+								
Anomalocera pattersoni					+	+								
Acartia clausi	+	+	+	+	+	+							+	
Oithona similis	+	+	+	+									+	
Oithona nana	+	+		+										
Euterpina acutifrons				+									+	
Copepod nauplii				+		+							+	
Oikopleura			+	+						+			+	
Young Gasteropods													+	
Young Lamellibranchs													+	
Fish eggs						+				+				
Fish larvæ						+								
	13	11	19	26	8	18	—	—	—	14	—	—	24	—

February.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Bahama Bank.	Lune Deep.	Port Erin.	Luce Bay.
Biddulphia mobiliensis ...	+	......	......	+	......	+	......	......	+	+	......	......	+	......
Biddulphia aurita	+	......	......	......	......	......	......	......	......	......	......	......	......	......
Chætoceros contortum ...	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Chætoceros criophilum ...	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Chætoceros decipiens	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Chætoceros teres	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Coscinodiscus concinnus ...	+	......	......	+	......	......	......	......	+	+	......	......	+	......
Coscinodiscus grani	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Rhizosolenia semispina ...	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Rhizosolenia setigera	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Rhizosolenia shrubsolei ...	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Ceratium furca	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Ceratium fusus	+	......	......	+	+	......	......	......	......	+	......	......	+	......
Ceratium tripos	+	......	......	+	......	......	......	......	......	......	......	......	+	......
Acanthometra sp.	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Noctiluca miliaris	+	......	......	......	......	......	......	......	......	......	......	......	......	......
Pleurobrachia pileus	+	+	......	+	......	......	......	......	......	......	......	......	......	......
Medusoid gonophores	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Sagitta bipunctata	+	+	......	+	......	+	......	......	+	+	+	......	+	......
Autolytus prolifer	......	......	......	......	......	+	......	......	+	+	+	......	......	......
Tomopteris onisciformis ...	......	......	......	......	......	+	......	......	+	......	+	......	+	......
Larval Polychæta............	......	......	......	......	......	......	......	......	......	......	......	......	+	......
" Mitraria "	+	......	......	+	......	+	......	......	......	......	......	......	+	......
Crab zoea	......	......	......	......	+	......	......	......	+	......	+	......	......	......
Mysis stage of Crangon ...	......	......	......	......	......	+	......	......	......	......	......	......	......	......
Young Mysis	......	......	......	......	......	+	......	......	+	......	+	......	......	......
Nyctiphanes norvegica ...	......	......	......	......	......	+	......	......	+	......	+	......	......	......
Eurydice pulchra	......	......	......	......	......	......	......	......	+	......	+	......	......	......
Hyperia galba	......	......	......	+	......	......	......	......	+	......	+	......	......	......
Parathemisto oblivia	......	......	......	+	......	......	......	......	......	......	......	......	......	......
Calanus heloglandicus	......	......	......	+	......	+	......	......	+	+	+	......	+	......
Pseudocalanus elongatus	......	......	......	+	......	+	......	......	+	......	+	......	+	......
Paracalanus parvus	+	+	......	+	......	+	......	......	+	+	+	......	+	......
Temora longicornis	......	+	......	+	......	+	......	......	+	......	......	......	......	......
Centropages hamatus	......	......	......	+	......	+	......	......	+	......	+	......	......	......
Centropages typicus	......	......	......	......	......	+	......	......	......	......	......	......	......	......
Anomalocera pattersoni ...	......	......	......	......	+	......	......	......	......	......	......	......	......	......
Acartia discaudata	......	......	......	......	......	+	......	......	......	......	......	......	......	......
Acartia clausi..................	+	+	......	+	+	+	......	......	......	+	+	......	......	......
Oithona similis	+	......	......	+	......	+	......	......	......	+	......	......	+	......
Oithona nana	+	......	......	+	......	......	......	......	......	......	......	......	......	......
Euterpina acutifrons	......	......	......	+	......	......	......	......	......	......	......	......	+	......
Copepod nauplii	......	......	......	+	+	+	......	......	......	......	......	......	+	......
Nauplii of barnacles	......	......	......	......	......	+	......	......	......	......	......	......	......	......
Oikopleura	......	......	......	+	+	......	......	......	......	+	......	......	+	......
Ascidian eggs	......	......	......	+	......	+	......	......	......	......	......	......	......	......
Young Gasteropods	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Young Lamellibranchs......	......	......	......	......	......	......	......	......	+	+	......	......	+	......
Fish eggs	......	......	......	+	+	+	......	......	+	......	+	......	+	......
Fish larvæ	......	......	......	......	......	......	......	......	......	......	+	......	......	......
	13	5	—	22	7	21	—	—	17	11	15	—	25	—

March.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Bahama Bank.	Lune Deep.	Port Erin.	Luce Bay.
Asterionella bleakleyi									+					
Bellerochoe malleus	+													
Biddulphia mobiliensis	+			+	+				+				+	
Biddulphia aurita	+			+										
Chætoceros contortum													+	
Chætoceros decipiens													+	
Coscinodiscus concinnus					+	+			+				+	
Rhizosolenia semispina						+			+					
Ceratium furca													+	
Ceratium fusus	+			+		+			+				+	
Ceratium tripos				+					+				+	
Acanthometra sp.													+	
Pleurobrachia pileus	+			+										
Medusoid gonophores									+				+	
Alcyonium eggs									+					
Echinoderm larvæ													+	
Sagitta bipunctata				+	+	+			+				+	
Autolytus prolifer				+	+	+		+					+	
"Mitraria"					+	+							+	
Crab zoea						+			+				+	
Mysis stage of Crangon	+			+		+								
Eurydice pulchra				+					+					
Bathyporeia pelagica				+										
Ampelisca spinipes				+										
Apherusa bispinosa				+										
Perioculodes longimanus				+										
Phoxocephalus fultoni				+										
Podon intermedium						+								
Calanus helgolandicus									+				+	
Pseudocalanus elongatus	+			+		+			+				+	
Paracalanus parvus				+				+	+				+	
Temora longicornis				+	+	+			+				+	
Centropages hamatus				+		+			+				+	
Acartia clausi				+	+	+		+	+				+	
Oithona similis				+									+	
Oithona nana													+	
Caligus rapax				+		+			+					
Copepod nauplii	+				+	+			+				+	
Nauplii of barnacles	+				+	+							+	
Ostracod stage of barnacles	+				+	+							+	
Oikopleura				+		+		+	+				+	
Ascidian eggs	+			+		+		+	+					
Young Gasteropods						+								
Fish eggs	+			+	+	+		+	+				+	
Fish larvæ				+		+			+					
	12	—	—	25	11	22	—	6	23	—	—	—	27	—

April.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Bahama Bank.	Lune Deep.	Port Erin.	Luce Bay.
Asterionella bleakleyi					+									
Biddulphia mobiliensis					+	+				+			+	
Chætoceros contortum													+	
Chætoceros criophilum													+	
Chætoceros decipiens													+	
Chætoceros teres													+	
Coscinodiscus concinnus					+	+		+		+			+	
Rhizosolenia semispina								+		+				
Rhizosolenia setigera								+		+				
Rhizosolenia shrubsolei								+		+				
Thalassiothrix curvata													+	
Ceratium furca								+					+	
Ceratium fusus								+		+			+	
Ceratium tripos								+		+			+	
Acanthometra sp.													+	
Alcyonium eggs								+		+			+	
Sagitta bipunctata				+	+	+		+					+	
Autolytus prolifer						+		+		+				
Larval Polychaeta													+	
"Mitraria"						+							+	
Crab zoea								+		+			+	
Crab megalopa								+						
Mysis stage of Crangon								+						
Pasiphea sivado								+						
Eurydice pulchra						+								
Eudorella truncatula								+						
Eudorellopsis deformis								+						
Calanus helgolandicus										+			+	
Pseudocalanus elongatus						+		+					+	
Paracalanus parvus								+		+			+	
Temora longicornis				+	+	+		+		+			+	
Centropages hamatus				+		+							+	
Acartia clausi				+	+	+		+		+			+	
Oithona similis													+	
Oithona nana													+	
Copepod nauplii						+		+		+			+	
Nauplii of barnacles					+	+							+	
Ostracod stage of barnacles					+	+							+	
Oikopleura								+		+			+	
Ascidian eggs								+		+				
Fish eggs					+	+		+		+			+	
Fish larvæ														
	—	—	—	4	9	14	—	24	—	18	—	—	29	—

May.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Bahama Bank.	Lune Deep.	Port Erin.	Luce Bay.
Asterionella bleakleyi	+													
Biddulphia mobiliensis	+	+	+	+	+			+					+	
Chætoceros contortum													+	
Chætoceros criophilum													+	
Chætoceros decipiens													+	
Chætoceros teres													+	
Coscinodiscus concinnus	+	+	+	+	+	+		+		+			+	
Coscinodiscus grani		+												
Rhizosolenia semispina	+	+	+	+	+	+		+		+		+	+	
Rhizosolenia setigera	+	+	+	+	+			+					+	
Rhizosolenia shrubsolei	+	+			+			+						
Ceratium furca	+					+				+				
Ceratium fusus	+	+	+	+				+		+		+		
Ceratium tripos	+	+	+	+				+		+			+	
Noctiluca miliaris	+		+											
Pleurobrachia pileus	+	+	+	+		+	+	+					+	
Sarsia tubulosa						+	+							
Medusoid gonophores		+					+			+			+	
Alcyonium eggs	+	+	+			+		+					+	
Sagitta bipunctata	+	+	+	+		+	+	+		+			+	
Autolytus prolifer					+	+	+			+			+	
Larval polychæta				+										
"Mitraria"		+		+		+				+				
Crab zoea		+	+	+	+	+	+			+		+		
Crab megalopa		+		+		+	+							
Mysis stage of Crangon		+		+		+				+		+		
Larval Nephrops				+		+	+	+						
Nyctiphanes norvegica				+			+							
Podon intermedium				+		+				+			+	
Evadne nordmanni		+				+								
Calanus helgolandicus					+		+						+	
Pseudocalanus elongatus						+	+	+					+	
Paracalanus parvus		+		+		+	+					+		
Temora longicornis		+		+	+	+	+	+		+			+	
Centropages hamatus				+	+	+	+	+						
Centropages typicus						+	+			+			+	
Anomalocera pattersoni		+				+							+	
Isias clavipes						+								
Acartia clausi		+		+	+	+	+	+		+		+	+	
Acartia discaudata						+								
Oithona similis													+	
Euterpina acutifrons													+	
Copepod nauplii	+	+	+	+	+	+		+				+	+	
Nauplii of barnacles				+	+	+		+					+	
Ostracod stage of barnacles				+	+	+							+	
Oikopleura	+	+		+		+				+			+	
Ascidian eggs		+	+	+						+				
Young Gasteropods													+	
Young Lamellibranchs		+											+	
Fish eggs		+		+	+	+	+	+		+		+	+	
Fish larvæ		+		+		+	+	+						
	15	27	13	27	15	30	18	19	—	18	—	8	30	—

June.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Bahama Bank.	Lune Deep.	Port Erin.	Luce Bay.
Biddulphia mobiliensis													+	
Biddulphia aurita						+								
Chætoceros decipiens													+	
Eucampia zoodiacus													+	
Melosira borreri													+	
Rhizosolenia semispina						+				+			+	
Rhizosolenia setigera													+	
Ceratium fusus				+		+				+				
Ceratium tripos				+		+				+			+	
Noctiluca miliaris				+										
Pleurobrachia pileus		+		+		+	+			+				
Medusoid gonophores				+			+			+			+	
Sarsia tubulosa							+							
Echinoderm larvæ						+								
Sagitta bipunctata		+				+	+			+				
Autolytus prolifer						+	+							
"Mitraria"		+				+								
Crab zoea		+		+		+	+			+				
Crab megalopa		+				+	+			+				
Mysis stage of Crangon		+		+		+								
Podon intermedium						+								
Evadne nordmanni		+				+								
Calanus helgolandicus						+	+						+	
Pseudocalanus elongatus				+		+	+			+				
Paracalanus parvus		+				+	+							
Temora longicornis		+		+		+	+			+			+	
Centropages hamatus				+		+	+							
Centropages typicus						+	+							
Anomalocera pattersoni		+				+								
Labidocera wollastoni		+												
Acartia clausi		+		+		+	+			+				
Acartia discaudata						+								
Oithona similis						+							+	
Copepod nauplii		+											+	
Nauplii of barnacles		+												
Ostracod stage of barnacles		+												
Oikopleura		+		+		+	+			+			+	
Ascidian eggs						+								
Young Gasteropods						+							+	
Young Lamellibranchs						+							+	
Fish eggs		+		+		+	+			+				
Fish larvæ		+				+	+			+				
	—	18	—	13	—	30	17	—	—	14	—	—	15	—

July.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Bahama Bank.	Lune Deep.	Port Erin.	Luce Bay.
Bellerochea malleus					+								+	
Biddulphia mobiliensis													+	
Chætoceros decipiens													+	
Eucampia zoodiacus													+	
Melosira borreri													+	
Rhizosolenia semispina		+											+	
Rhizosolenia setigera													+	
Ceratium furca		+							+					
Ceratium fusus		+	+						+					
Ceratium tripos	+	+	+			+			+				+	
Noctiluca miliaris	+	+	+	+	+	+			+					
Pleurobrachia pileus		+		+	+				+					
Young Aurelia													+	
Medusoid gonophores				+									+	
Echinoderm larvæ		+												
Sagitta bipunctata		+				+							+	
Autolytus prolifer													+	
Tomopteris onisciformis													+	
Larval Polychæta		+		+									+	
"Mitraria"		+		+										
Crab zoea	+	+		+	+	+			+				+	
Crab megalopa	+			+	+	+			+				+	
Mysis stage of Crangon				+	+	+							+	
Young Mysis				+										
Larval Squilla						+								
Larval Lobsters						+								
Podon intermedium		+		+		+							+	
Evadne nordmanni		+				+			+				+	
Calanus helgolandicus						+							+	
Pseudocalanus elongatus						+			+				+	
Paracalanus parvus						+							+	
Temora longicornis	+	+	+	+	+	+							+	
Centropages hamatus	+	+	+	+	+	+			+				+	
Centropages typicus						+								
Anomalocera pattersoni	+	+			+	+			+				+	
Labidocera wollastoni		+				+								
Isias clavipes						+							+	
Acartia clausi		+		+	+	+			+				+	
Acartia discaudata						+								
Oithona similis													+	
Copepod nauplii													+	
Ostracod stage of barnacles						+								
Oikopleura	+	+		+					+				+	
Ascidian eggs		+												
Young Lamellibranchs		+											+	
Young Gasteropods													+	
Fish eggs	+	+		+	+	+			+				+	
Fish larvæ	+	+	+		+	+								
	10	23	6	15	12	24	—	—	14	—	—	—	33	—

August.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Bahama Bank.	Lune Deep.	Port Erin.	Luce Bay.
Bacillaria paradoxa			+	+										
Biddulphia mobiliensis				+									+	
Biddulphia aurita				+										
Chætoceros decipiens													+	
Nitzschia seriata				+										
Rhizosolenia semispina				+										
Ceratium furca			+	+								+	+	
Ceratium fusus		+	+	+								+	+	
Ceratium tripos		+	+	+		+						+	+	
Noctiluca miliaris		+	+	+		+						+	+	
Pleurobrachia pileus				+									+	
Medusoid gonophores			+										+	
Sagitta bipunctata		+	+	+		+						+	+	
Autolytus prolifer													+	
Tomopterisonisciformis													+	
Larval Polychæta													+	
"Mitraria"												+		
Crab zoea		+	+	+		+						+	+	
Crab megalopa		+		+		+							+	
Mysis stage of Crangon				+		+							+	
Larval Jaxea						+								
Larval Squilla						+								
Parathemisto oblivia				+										
Idotea marina													+	
Eurydice spinigera				+										
Eurydice pulchra				+										
Podon intermedium				+		+							+	
Evadne nordmanni						+							+	
Calanus helgolandicus				+		+							+	
Pseudocalanus elongatus													+	
Paracalanus parvus						+						+	+	
Temora longicornis		+	+	+		+							+	
Centropages hamatus		+	+	+		+						+	+	
Centropages typicus						+								
Candacia armata													+	
Isias clavipes						+							+	
Anomalocera pattersoni		+				+							+	
Labidocera wollastoni						+								
Pontella lobiancoi						+								
Parapontella brevicornis													+	
Acartia clausi		+	+	+		+						+	+	
Acartia discaudata						+								
Oithona similis			+	+									+	
Caligus rapax													+	
Copepod nauplii													+	
Ostracod stage of barnacles			+	+		+								
Oikopleura			+	+		+							+	
Young Gasteropods													+	
Young Lamellibranchs													+	
Fish eggs				+									+	
Fish larvæ						+								
	—	10	14	26	—	24	—	—	—	—	—	10	35	—

September.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Laxey Bay.	Lune Deep.	Port Erin.	Luce Bay.
Asterionella bleakleyi	+	+	+	......	......	......	......	......	......	......	......	......	......	......
Bacillaria paradoxa	+	+	+	+	......	......	......	......	......	......	......	......	......	......
Bacteriastrum delicatulum	+	+	+	......	......	......	......	......	......	......	......	......	......	......
Bellerochoe malleus	+	+	......	......	......	......	......	......	......	......	......	......	......	......
Biddulphia mobiliensis ...	......	......	......	+	......	......	......	......	......	......	......	......	+	......
Chætoceros contortum ...	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Chætoceros decipiens	......	+	+	+	+	......	......	......	......	......	......	......	+	......
Chætoceros teres	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Coscinodiscus concinnus ...	+	+	+	......	......	......	......	......	......	......	......	......	+	......
Coscinodiscus grani	+	+	+	......	......	......	......	......	......	......	......	......	......	......
Nitzschia seriata	+	+	+	......	......	......	......	......	......	......	......	......	......	......
Rhizosolenia semispina ...	......	+	+	+	......	......	......	......	......	......	......	......	+	......
Rhizosolenia setigera	......	+	......	......	......	......	......	......	......	......	......	......	......	......
Rhizosolenia shrubsolei ...	+	+	+	+	......	......	......	......	......	......	......	......	+	......
Ceratium furca	+	+	+	+	......	......	......	......	......	......	......	......	+	......
Ceratium fusus	+	+	+	+	......	......	......	......	......	......	......	......	+	......
Ceratium tripos	+	+	+	+	......	......	......	......	......	......	......	......	+	......
Tintinnopsis campanula ...	+	+	+	......	......	......	......	......	......	......	......	......	+	......
Noctiluca miliaris	+	+	+	+	......	+	......	......	......	......	......	......	......	......
Pleurobrachia pileus	+	+	+	+	+	......	......	......	......	......	......	......	+	......
Larval Aurelia	+	......	......	......	......	......	......	......	......	......	......	......	......	......
Medusoid gonophores	......	+	+	+	+	+	......	......	......	......	......	......	+	......
Larval Echinoderms	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Sagitta bipunctata	+	+	+	+	+	+	......	......	......	......	+	......	+	......
Autolytus prolifer	......	......	......	......	......	......	......	......	......	......	+	......	+	......
Tomopteris onisciformis ...	......	......	......	+	......	......	......	......	......	......	......	......	+	......
Larval Polychæta	......	......	......	+	......	......	......	......	......	......	......	......	+	......
"Mitraria"	......	......	......	+	......	+	......	......	......	......	......	......	+	......
Larval Lobster	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Crab zoea	+	......	+	......	+	+	......	......	......	......	+	......	+	......
Crab megalopa	+	+	+	+	......	+	......	......	......	......	+	......	+	......
Mysis stage of Crangon ...	+	+	......	+	+	......	......	......	......	......	+	......	+	......
Mysis	+	+	......	+	......	......	......	......	......	......	......	......	+	......
Larval Cumacea	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Eurydice spinigera	......	......	......	......	......	+	......	......	......	......	......	......	......	......
Eurydice inermis	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Idotea marina	......	......	......	......	......	+	......	......	......	......	......	......	+	......
Hyperia galba	......	......	......	+	......	......	......	......	......	......	......	......	......	......
Parathemisto oblivia	......	......	......	+	......	......	......	......	......	......	......	......	......	......
Apherusa bispinosa	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Dexamine spinosa	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Gammarus	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Paratylus swammerdami	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Perioculodes longimanus ...	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Asterope mariæ	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Philomedes interpuncta ...	......	......	......	......	......	......	......	......	......	......	......	......	+	......
Podon intermedium	+	+	+	......	......	......	......	......	......	......	+	......	+	......

September.—*Continued.*

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Laxey Bay	Lune Deep.	Port Erin.	Luce Bay.
Evadne nordmanni													+	
Calanus helgolandicus	+										+		+	
Pseudocalanus elongatus											+		+	
Paracalanus parvus				+		+					+		+	
Temora longicornis	+	+	+	+		+					+		+	
Metridia lucens													+	
Candacia armata											+		+	
Centropages hamatus	+	+	+	+	+	+					+		+	
Centropages typicus											+			
Anomalocera pattersoni					+						+		+	
Labidocera wollastoni		+	+										+	
Parapontella brevicornis													+	
Isias clavipes											+		+	
Acartia clausi	+	+	+	+	+	+					+		+	
Oithona similis		+									+		+	
Euterpina acutifrons		+											+	
Monstrilla anglica													+	
Monstrilla longicornis													+	
Copepod nauplii		+											+	
Ostracod stage of barnacles	+	+	+											
Oikopleura	+	+	+	+							+		+	
Ascidian eggs						+							+	
Young Gasteropods						+							+	
Young Lamellibranchs													+	
Fish eggs				+									+	
Fish larvæ				+							+			
	27	32	26	27	9	14	—	—	—	—	19	—	58	—

October.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Laxey Bay	Lune Deep.	Port Erin.	Luce Bay.
Bellerochoe malleus	+			+										
Biddulphia mobiliensis				+									+	
Biddulphia aurita				+										
Chætoceros contortum													+	
Chætoceros decipiens	+			+									+	+
Chætoceros teres													+	
Coscinodiscus concinnus	+			+									+	+
Coscinodiscus grani	+			+										
Rhizosolenia semispina	+			+									+	
Rhizosolenia setigera	+			+										
Rhizosolenia shrubsolei	+			+									+	
Ceratium fusus	+			+									+	+
Ceratium furca	+			+										+
Ceratium tripos	+			+									+	+
Trochiscia brachiolata	+													
Tintinnopsis campanula													+	+
Noctiluca miliaris	+			+		+								
Pleurobrachia pileus				+										
Medusoid gonophores	+					+							+	
Echinoderm larvæ				+									+	
Sagitta bipunctata	+			+		+							+	
Autolytus prolifer													+	
Tomopteris onisciformis				+									+	
Larval Polychæta													+	
"Mitraria"	+			+		+								
Crab zoea				+		+								+
Crab megalopa						+								+
Mysis stage of Crangon				+										+
Mysis														+
Eurydice spinigera						+								
Podon intermedium						+							+	
Evadne nordmanni						+								+
Calanus helgolandicus				+									+	+
Pseudocalanus elongatus													+	
Paracalanus parvus	+			+		+							+	+
Temora longicornis	+			+		+							+	+
Centropages hamatus	+			+		+								+
Anomalocera pattersoni	+			+										+
Labidocera wollastoni						+								
Pontella lobiancoi						+								
Acartia clausi	+			+		+							+	+
Acartia discaudata						+							...	+
Oithona similis	+			+									+	+
Oithona nana	+			+										
Copepod nauplii	+			+									+	
Oikopleura				+		+							+	+
Ascidian eggs													+	+
Young Gasteropods						+							+	
Young Lamellibranchs													+	
	23	—	—	30	—	18	—	—	—	—	—	—	28	21

November.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Laxey Bay.	Lune Deep.	Port Erin.	Luce Bay.
Asterionella bleakleyi		+				+			+		+			
Biddulphia mobiliensis						+			+		+		+	
Chætoceros constrictum									+		+			
Chætoceros debile									+		+			
Chætoceros decipiens									+		+		+	
Chætoceros teres									+		+			
Coscinodiscus concinnus		+		+		+			+		+		+	
Coscinodiscus grani		+		+										
Ditylium brightwelli									+		+			
Eucampia zoodiacus									+		+			
Melosira borreri									+		+			
Rhizosolenia semispina						+			+		+		+	
Rhizosolenia setigera														
Rhizosolenia shrubsolei		+		+		+			+		+		+	
Ceratium furca				+					+		+			
Ceratium fusus		+		+		+			+		+		+	
Ceratium tripos		+		+					+		+		+	
Tintinnopsis campanula									+				+	
Noctiluca miliaris		+		+					+		+			
Pleurobrachia pileus						+			+				+	
Medusoid gonophores		+												
Sagitta bipunctata		+		+		+			+		+		+	
Autolytus prolifer													+	
Tomopteris onisciformis						+								
Larval Polychæta									+		+		+	
"Mitraria"						+			+		+			
Crab zoea				+									+	
Crab megalopa		+		+										
Mysis stage of Crangon						+								
Mysis				+										
Idotea marina						+								
Hyperia galba						+								
Calanus helgolandicus				+		+			+		+		+	
Pseudocalanus elongatus						+			+		+		+	
Paracalanus parvus		+		+		+			+		+		+	
Temora longicornis		+		+		+			+				+	
Centropages hamatus		+		+		+								
Labidocera wollastoni						+								
Acartia clausi		+		+		+			+		+		+	
Oithona similis		+				+			+		+		+	
Caligus rapax						+								
Copepod nauplii									+		+		+	
Oikopleura						+			+				+	
Ascidian eggs													+	
Fish larvæ						+								
	—	15	—	16	—	24	—	—	29	—	25	—	22	—

December.

	Blackpool.	Ribble Estuary.	Mersey Estuary.	Rhyl to Red Wharf Bay.	Carnarvon Bay.	Cardigan Bay.	Fishguard Bay.	Off Shore Stn. No. 1.	Off Shore Stn. No. 2.	Off Shore Stn. No. 3.	Laxey Bay	Lune Deep.	Port Erin.	Luce Bay.
Coscinodiscus concinnus										+				
Ceratium fusus										+				
Sagitta bipunctata						+								
"Mitraria"										+				
Calanus helgolandicus						+								
Pseudocalanus elongatus						+				+				
Paracalanus parvus						+				+				
Temora longicornis						+				+				
Centropages hamatus						+				+				
Anomalocera pattersoni						+								
Acartia clausi						+				+				
Copepod nauplii										+				
Fish larvæ						+								
	—	—	—	—	—	9	—	—	—	9	—	—	—	—

Occurrence of Pelagic Fish Eggs.

The following table shows the distribution, month by month, in four divisions of the Irish Sea, of the species named during 1906:—

In Territorial Waters from Blackpool to Red Wharf Bay.

Months.	Plaice.	Dab.	Flounder.	Brill.	Turbot.	Norway Top Knot.	Lemon Sole.	Long Rough Dab.	Solenette.	Variegated Sole.	Scald Fish.	Cod.	Haddock.	Whiting.	Bib.	Coal Fish.	Ling.	Rockling.	Gurnard.	Common Dragonet.	Spotted Dragonet.	Weever.	Sprat.	Anchovy.	Mackerel.
February	+	...	+	...	...	...	...	...	...	...	...	+	+	...	...	+	...	...	...	...	...	...	...	...	...
March	+	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	+	...	...	...	...	...	...	...
April	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...
May	...	...	...	...	...	...	...	...	+	+	...	...	...	...	...	...	...	+	...	+	...	...	+	...	...
June	...	...	...	+	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+
July	...	...	...	...	...	+	...	...		...	...	...	...	...	...	...	...	+	...	...	...	+	...	...	...
August	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	+	...	...	...
September	...	...	...	...		...		...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...

In Cardigan Bay.

Months.	Plaice.	Dab.	Flounder.	Brill.	Turbot.	Norway Top Knot.	Lemon Sole.	Long Rough Dab.	Solenette.	Variegated Sole.	Scald Fish.	Cod.	Haddock.	Whiting.	Bib.	Coal Fish.	Ling.	Rockling.	Gurnard.	Common Dragonet.	Spotted Dragonet.	Weever.	Sprat.	Anchovy.	Mackerel.
January	+	...	...	...	...	...	...	...	...	...	...	...	...		...	...	...	+	...	...	...	...	...	...	...
February	+	...	...	...	...	...	...	...	...	...	...	...	...	...	+	+	...	+	...	+	...	...	...	...	...
March	+	...	...	...	...	...	...	...	...	...	...	...	+	+	+	+	...	+	...	...	...	...	...	...	...
April	+	...	...	...	...	...	...	...	...	...	...	...	...	+	...	+	...	+	...	...	+	...	+	...	...
May	+	+	...	+	...	...	...	...	+	+	...	...	+	+	...	...	+	+	+	...	+	...	+	...	...
June	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	+	+	...	...	+	...	+	+
July	...	...	...	+	...	+	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	+	+	...	+
August	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...

On Off-shore Grounds, N.W. of Piel to Liverpool N.W. Light Ship.

Months.	Plaice.	Dab.	Flounder.	Brill.	Turbot.	Norway Top Knot.	Lemon Sole.	Long Rough Dab.	Solenette.	Variegated Sole.	Scald Fish.	Cod.	Haddock.	Whiting.	Bib.	Coal Fish.	Ling.	Rockling.	Gurnard.	Common Dragonet.	Spotted Dragonet.	Weever.	Sprat.	Anchovy.	Mackerel.
January……	+	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
February……	+	…	+	…	…	…	…	…	…	…	…	+	+	…	+	…	…	…	…	…	…	…	…	…	…
March……	+	+	+	…	…	…	…	…	…	…	…	+	+	+	+	…	…	+	…	…	…	…	…	…	…
April……	…	+	…	…	…	…	…	…	…	…	…	…	+	+	+	…	…	…	…	+	…	…	+	…	…
May……	…	+	…	…	…	…	…	…	…	+	+	…	…	…	…	…	…	…	+	…	…	+	…	…	…
June……	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	+	…	…	…
July……	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	+	…	…	…

In Vicinity of Port Erin.

Months.	Plaice.	Dab.	Flounder.	Brill.	Turbot.	Norway Top Knot.	Lemon Sole.	Long Rough Dab.	Solenette.	Variegated Sole.	Scald Fish.	Cod.	Haddock.	Whiting.	Bib.	Coal Fish.	Ling.	Rockling.	Gurnard.	Common Dragonet.	Spotted Dragonet.	Weever.	Sprat.	Anchovy.	Mackerel.
February……	+	…	…	…	…	…	…	…	…	…	…	…	…	…	+	…	…	+	…	…	…	…	…	…	…
March……	+	…	…	…	…	…	…	…	…	…	…	…	…	+	+	…	…	+	…	+	…	…	…	…	…
April……	…	…	…	…	…	…	…	+	+	…	…	…	…	+	…	…	+	+	+	+	…	…	+	…	…
May……	…	…	…	…	…	…	+	…	+	…	…	…	+	…	…	…	…	+	…	+	…	…	+	…	…
June……	…	…	…	…	…	+	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
July……	…	…	…	+	+	…	…	…	…	…	…	…	…	…	…	…	…	+	…	…	+	…	+	…	…
August……	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	+	…	…	…	+	+	…	+
September…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	+	…	…	…	+	+	…	…

FAUNISTIC NOTES.

By Andrew Scott.

Young Fishes, *Leptocephalus morrisii*—Plate V.

A perfect specimen of the tape worm form of the *Leptocephalus* stage of the conger eel was found by a local fisherman on April 30th, 1906. The fish was discovered in a small pool of water, left by the receding tide, on the shore, on the east side of Foulney Island. The Leptocephalus was living when captured, but as the fisherman had no means of keeping it alive it soon died. The man handed the specimen over to me soon after he got it. It was then fresh and perfectly transparent, quite soft and flexible. It was so transparent that ordinary print could be easily read through it when placed on a piece of newspaper. In extreme length it measured 118 mm. The weight of the fish after removing the superfluous water was 1·2 grammes, and its volume 1·5 cubic centimetres. The greatest dorso-ventral height of the body was 9 mm., and it was broadest about 65 mm. from the tip of the snout. The myotomes were fairly distinct, and 151 were counted. The fish was colourless, with the exception of a row of black specks along each side of the ventral margin of the anterior half. There was also a similar row of specks along the lateral line, beginning near the greatest height and extending to the tail. The black specks appeared to be placed at the junction of the myotomes, and were very crowded towards the tail. The presence of this rare form so far inshore is apparently unusual. The specimen captured was probably only a wandering individual, as no more have been seen. The figure is from a photograph, and represents the natural size of the fish.

Amongst the other young fishes found in the tow-nettings we have to record the occurrence of **post-larval herrings**. On January 23rd, 1906, a large number were found in a surface tow-netting taken off the Patches Buoy, Cardigan Bay, and also on the same day, off Llanon. A surface tow-netting taken in the vicinity of the Bahama Light Ship, on February 20th, contained one specimen, another tow-netting from Conway Bay, on March 5th, contained three. The majority of these young fish measured 15 mm. in length, one or two 25 mm., and one 35 mm. The other young fishes have already been dealt with.

Fish Eggs.—A table showing the distribution from month to month is given above. The first occurrence of plaice eggs during 1906 was in tow-nettings from the Patches Buoy, off Llanon, in Cardigan Bay, on January 23rd. They were again obtained from near the Liverpool North-west Light Ship, on January 31st. From the latter date onwards to the end of March, plaice eggs were tolerably common in many of the tow-nettings taken in the open sea, and in territorial waters. The eggs of the Anchovy were found in tow-nettings taken off Aberdovey, on June 14th, and July 23rd. This is only the second time we have met with Anchovy eggs during a period of ten years. Their occurrence in British seas was first noticed by the late R. L. Ascroft in 1896. The eggs were taken in a surface tow-netting from off Lytham Pier, and identified by Professor McIntosh. The following fish eggs taken in 1906 have not previously been observed in the plankton of the Irish sea. Long Rough Dab: One specimen of the characteristic eggs of this fish was taken at Port Erin, on April 9th. The egg of the Long Rough Dab is about the same size as the plaice egg, but is easily recognised by the large size of the

space between the egg capsule and the yolk. Variegated Sole: A few specimens were found in a tow-netting from the vicinity of Nelson Buoy, at the entrance to the Ribble, on May 31st, and in another from Lune Deep, about five miles south of Piel Gas Buoy, on May 14th. Ling: The eggs of this fish were taken off Port Erin on April 9th, and off New Quay Head on May 1st. Mackerel: Large numbers of eggs belonging to this fish were found in the plankton samples from various parts of Cardigan Bay in June and July, off the entrance to the Ribble in the latter half of June, along the North Wales coast about the same time, and in the vicinity of Port Erin on August 27th. A very extensive incursion of adult mackerel took place during 1906. The fish were caught in various parts of the Irish Sea, between New Quay and the Duddon, from the beginning of June right on to the end of September. Two species of ecto-parasites of fishes were taken for the first time in the Irish Sea in 1906.

Caligus zei, Norman and T. Scott. Plate I.

Several specimens of this species were found attached to the skin of a "John Dory" captured in the trawl of the "John Fell," while fishing off New Quay Head, on June 16th. The only other known specimens of this species are in Dr. Norman's collection, and were taken on a "John Dory" captured off the coast of Cornwall forty years ago. The female represented by the drawing on the plate measured 6 mm. in length.

Lernæenicus encrasicoli (Turton). Plate II, figs. 6-9.

A large catch of sprats were taken off Blackpool on February 19th, by the fisheries steamer, and a few hundred of these fish were landed at Piel. A careful examination of the fish was made, and one sprat with

two of the above-mentioned parasites attached to it, and another with one, were found. The parasites were embedded in the tissues at the anterior end of the dorsal fin. On dissecting one out it was found that the head had penetrated to the visceral cavity. Fig. 6 represents the natural size of the sprat and its parasite, and also shows the position of attachment. Fig. 7 represents a dissection showing the head of the parasite passing into the visceral cavity. Figs. 8 and 9 represent two views of the head and illustrate the difference between *L. encrasicoli* and *L. sprattæ*.

The following ecto-parasites of fishes have been taken within the past few years, but illustrations are now given to show the differences in the appendages.

Lernæenicus sprattæ (Sowerby). Plate II, figs. 1-5.

This parasite is not uncommon on the sprats captured along the Lancashire coast. It differs in the manner of attachment to its host from *L. encrasicoli*. All the specimens of *L. sprattæ* that we have seen were attached to the eye, as shown in the illustration. The barbed head is inside the eye, and the parasite apparently feeds on the semifluid matter. The neck of the parasite is corrugated for some distance from the point of its attachment to the body. In *L. encrasicoli* the neck is quite smooth. The lateral projections of the head differs somewhat in the two species. In *L. sprattæ* they are directed backwards, and in *L. encrasicoli* they are nearly at right angles to the head. The appendages in the two species appear to be identical, and consist of one pair of antennules, one pair of antennæ, and four pairs of rudimentary feet. The four pairs of feet have probably remained in the same condition from the free-swimming larval period.

Lernanthropus kroyeri, van Beneden. Plate III.

We find this parasite occasionally attached to the gills of Bass (*Labrax lupus*), caught at the entrance to Barrow Channel. When living the animal is a dark red colour, and rather difficult to see. It differs from any of the other ecto-fish parasites with which I am acquainted by the possession of a peculiar appendage situated close to the base of the antennules of both sexes. The appendage is of irregular shape, somewhat pointed towards the apex, and apparently composed of two joints. Its situation and structure are shown by fig. 3 on the plate. The female is about 21·7 mm. in length, inclusive of the thoracic appendages. The male is rather different from the female and is about 10·5 mm. long. It apparently lives as a parasite on the female. I have never come across any that were isolated, and living directly on the gills of the fish. The appendages are nearly identical in the two sexes. They consist of one pair of seven-jointed antennules, with secondary processes, one pair of antennæ, one pair of mandibles enclosed in a suctorial tube, one pair of maxillæ, two pairs of maxillipedes, and two pairs of rudimentary feet. The outer branch of the second pair of feet of the male has a slightly different armature from that found on the second pair of the female. The outer branch of the female second foot is armed with four spines, while the male has two small spines and a number of minute teeth at the apex of the branch. The furca are large and conspicuous. The spermatophores frequently found attached to the female are globular in shape, and of a dark brown colour.

Clavella labracis ?, van Beneden. Plate IV.

While trawling in Luce Bay for large plaice for the tanks, a few *Crenilabrus melops* were captured amongst

the other fishes. One of these was dissected and a few *Clavella* were found attached to the gill filaments. In general appearance the parasite resembles van Beneden's species which we have already recorded for the Irish Sea from another kind of wrasse. Our first specimens were found on the gills of the Ballan wrasse (*Labrus bergylta*). The present species is a very small one, and is only 1 mm. in length, exclusive of the egg sacs. The species has only one pair of maxillipedes. The antennules are five jointed and armed with short spatulate hairs, the first joint has a short, thick hair placed on the lower margin near the junction with the second joint. The antenna are in the form of very strong slender hooks. The mandibles and maxilla are rudimentary; the former appears to have no serrate apex. There are two pairs of rudimentary feet, both two-branched. The first pair has both branches composed of two joints, while the second pair has a two-jointed outer branch, and a three-jointed inner branch. The furca are very small and inconspicuous. No males were found.

Explanation of the Plates.

Plate I.

Caligus zei, Norman and T. Scott.—

Fig. 1.—Adult female seen from above. ×11.
,, 2.—Antennule.
,, 3.—Antenna.
,, 4.—Sternal fork.
,, 5.—First maxilliped.
,, 6.—Second maxilliped.
,, 7.—Fourth foot.
,, 8.—Abdomen of male.

Plate II.

Fig. 1.—*Lernæenicus sprattæ* (Sowerby), in situ. Natural size.
,, 2.—*Lernæenicus sprattæ*, removed from its host. × 2·5.
,, 3.—Head and anterior portion of thorax of *L. sprattæ*. × 5.
,, 4.—Antennule. × 126.
,, 5.—Antenna. × 80.
,, 6.—*Lernæenicus encrasicoli* (Turton), in situ. Natural size.
,, 7.—Dissection showing position of head in the host. × 3.
,, 8.—Head and anterior portion of thorax, from above. × 6.
,, 9.—Head and anterior portion of thorax, from left side. × 6.

Plate III.

Lernanthropus kroyeri, van Beneden.

Fig. 1.—Adult female, seen from above. × 13·4.
,, 2.—Antennule and secondary process. × 120.
,, 3.—Antenna. × 60.
,, 4.—Mandible. × 181.
,, 5.—Maxilla. × 181.
,, 6.—First maxilliped. × 90.
,, 7.—Second maxilliped. × 90.
,, 8.—First foot. × 90.
,, 9.—Second foot. × 90.
,, 10.—Outer branch of second foot, male. × 90.
,, 11.—Abdomen and furca of female, with spermatophores. × 90.
,, 12.—Adult male seen from above. × 13·4.
,, 13.—Abdomen and furca of male. × 90.

Plate IV.

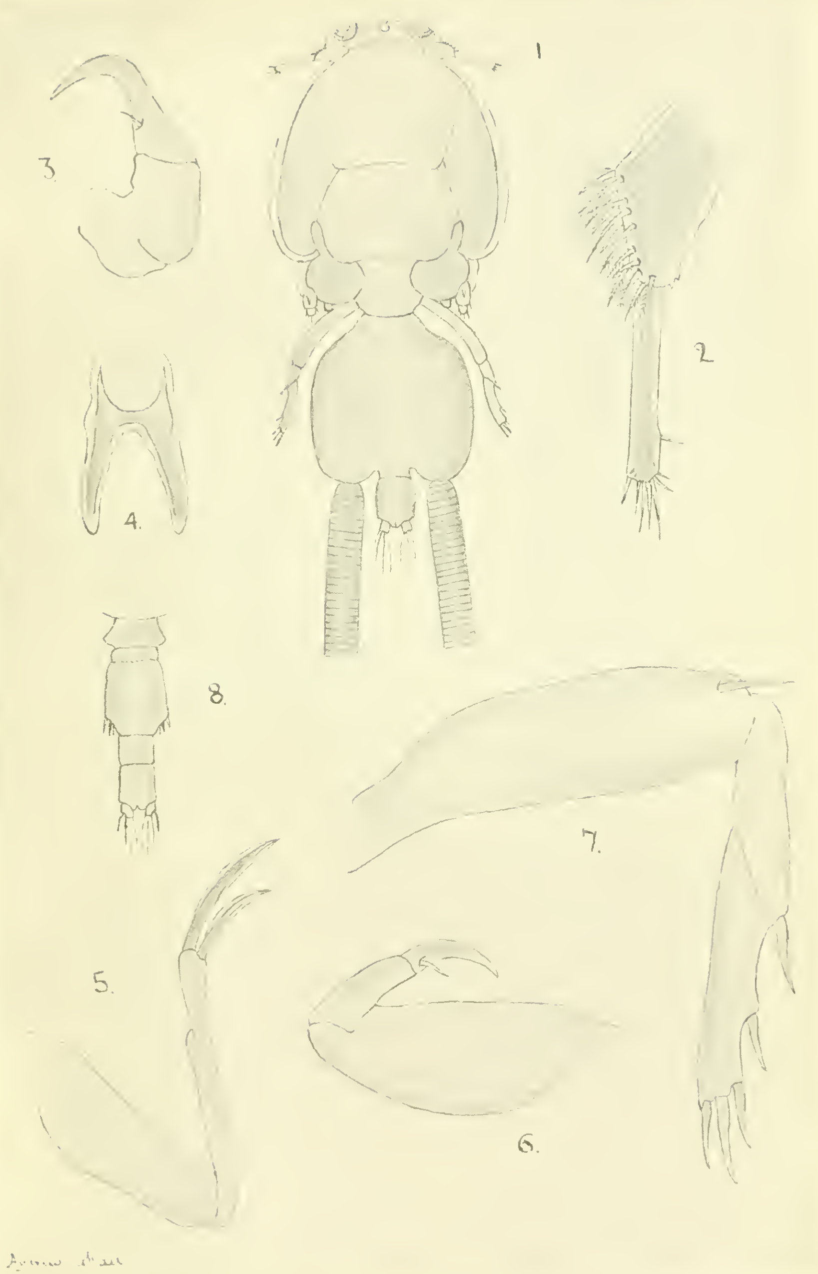
Clavella labracis, van Beneden.

Fig. 1.—Adult female seen from above. × 45.
,, 2.—Antennule. × 390.
,, 3.—Antenna. × 390.
,, 4.—Mandible. × 781.
,, 5.—Maxilla. × 781.
,, 6.—Maxilliped. × 390.
,, 7.—First foot. × 390.
,, 8.—Second foot. × 390.
,, 9.—Abdomen and furca. × 390.

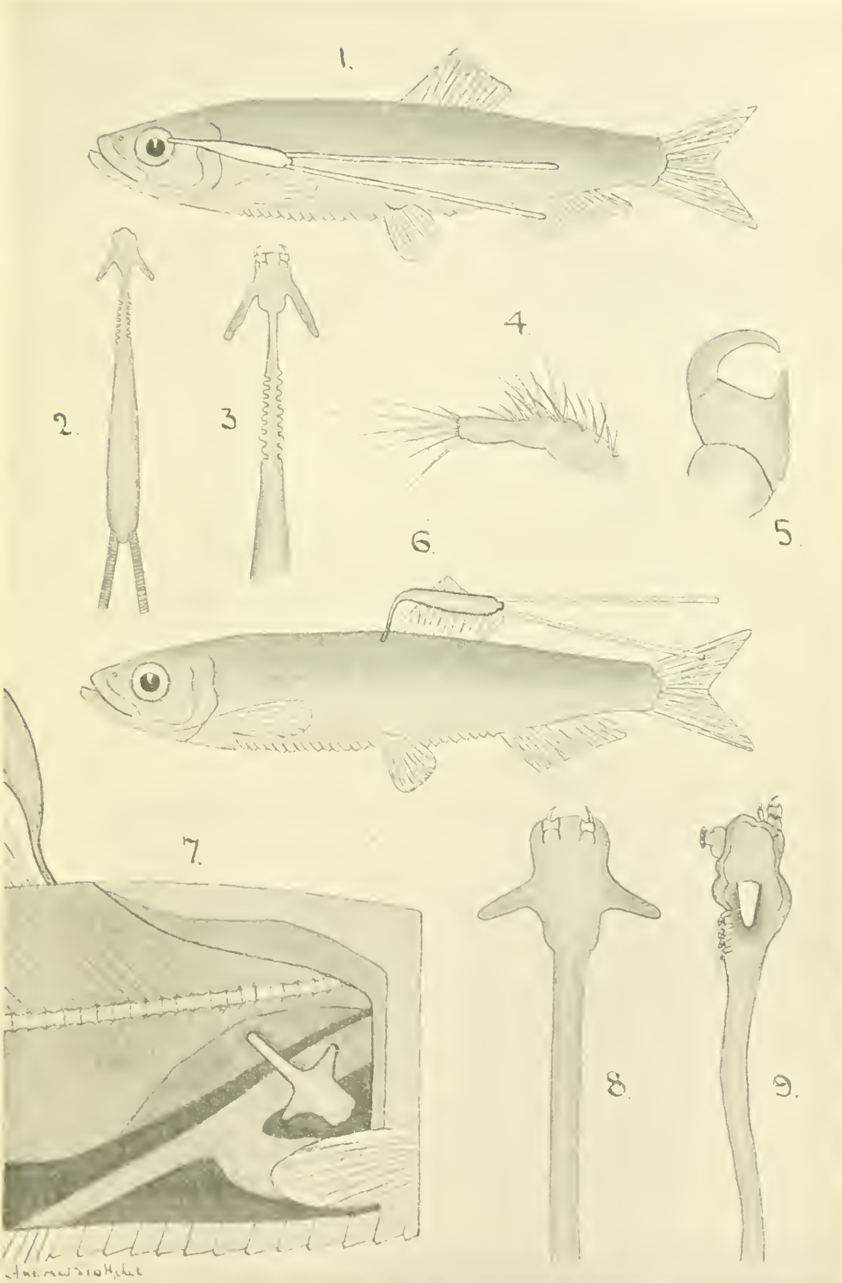
Plate V.

Leptocephalus morrisii

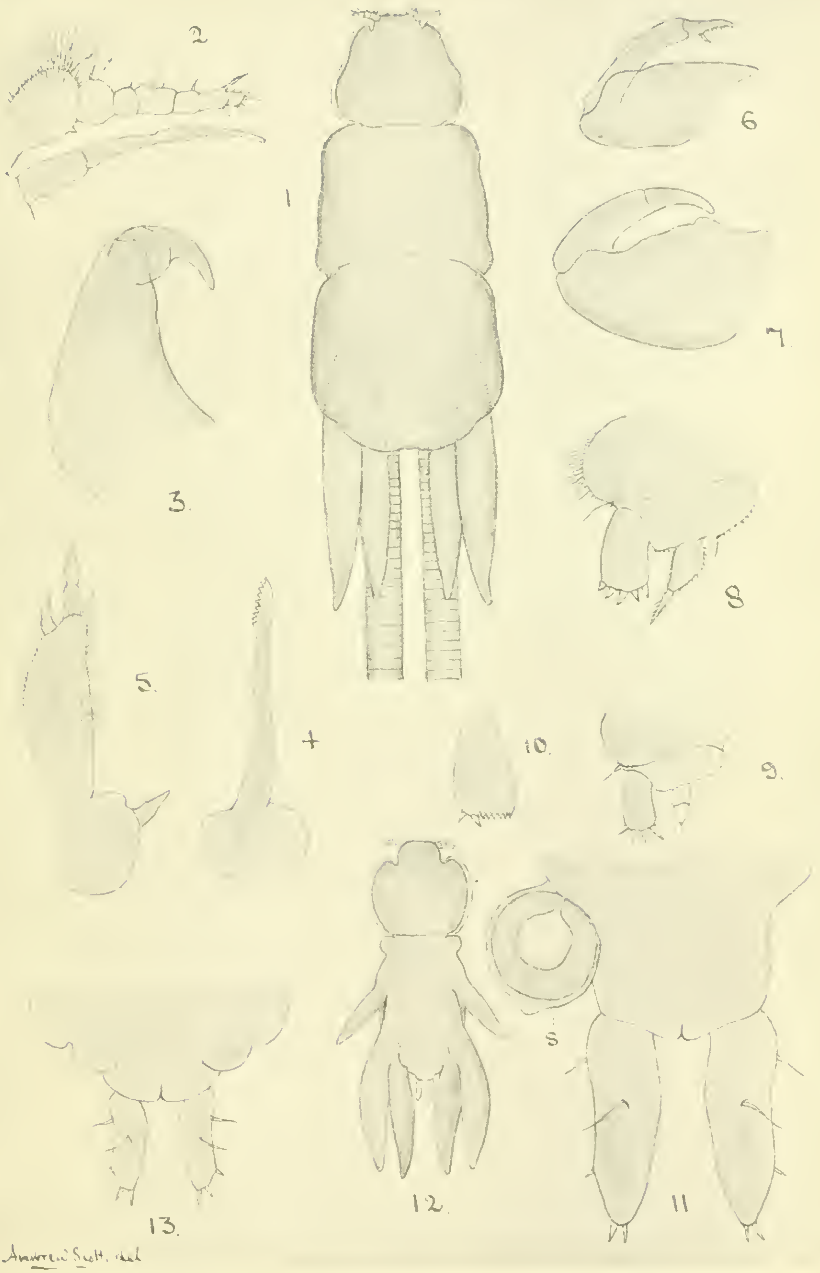
Natural size, and seen from the right side.



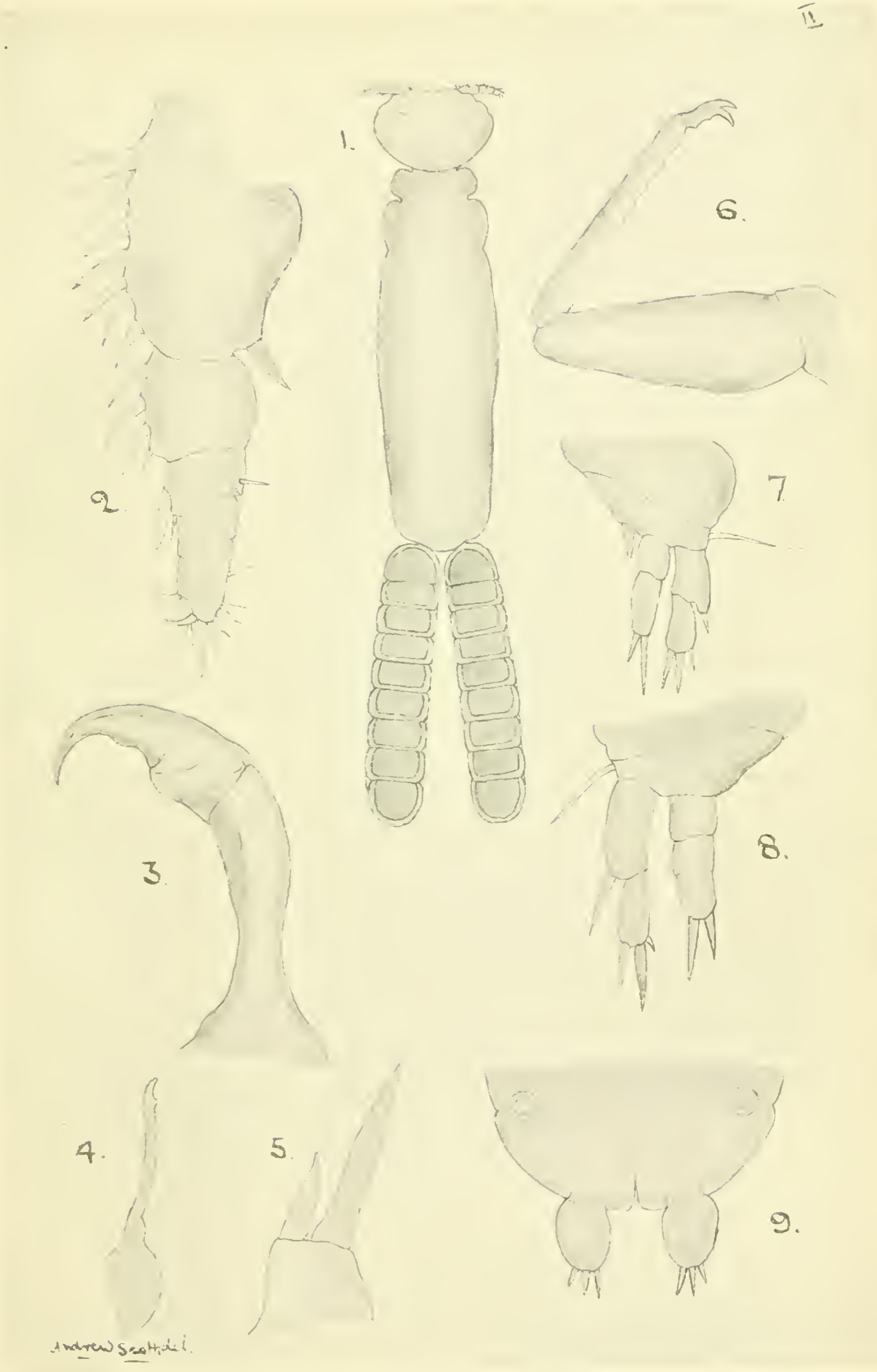
Caligus zei, Norman and T. Scott.



Figs. 1–5. Lernæenicus sprattæ (Sowerby).
Figs. 6–9. Lernæenicus encrasicoli (Turton).



LERNANTHROPUS KROYERI, van Beneden.



CLAVELLA LABRACIS, van Beneden.

PLATE V.

Leptocephalus stage of Conger Eel. Nat. size.

NOTES ON THE FOOD OF YOUNG FISHES.

By Andrew Scott.

The tow-nettings taken during the summer months frequently contain the post-larval, and later stages of various kinds of fishes. In some cases identification is tolerably easy. In others, the work of assigning the post larval fishes to any particular species, is sometimes an impossibility. These tender objects are very easily mutilated in capture. In all cases, even when the young fishes cannot be identified with certainty, the stomach and intestines are now being examined to find out what the fish has been feeding on. The internal organs owing to the size of the fish, are naturally small, and cannot be examined in the ordinary way. The methods adopted in this work which give fairly satisfactory results are, (1) removing the entire alimentary system with the aid of a low power dissecting microscope, then carefully dissecting the stomach under a Zeiss A, or Leitz No. 3 objective, a cover glass is next put on, and the whole contents carefully gone over; (2) dehydrating, clearing, and mounting the stomach, or even the whole fish, in the ordinary way for a permanent preparation in Canada balsam. The former method has the advantage that little time is taken up in the work. The latter one may take a few hours, and the results do not always repay the labour involved. As a rule, the shorter method is now employed. All the young fishes examined were caught by an ordinary open tow-net, worked just under the surface of the sea. The following are the fishes that have been examined, with the locality of capture, size in millimetres, and food found.

Post-larval Cottus.

Locality.	Millimetres.	Food.	Remarks.
1 Near Duddon Bar. 20.3.06.	9	3 *Temora longicornis.* 1 *Oithona similis.*	*Temora* rare and *Oithona* absent in plankton.
1 off Llanbedrog, Cardigan Bay, 27.4.06.	8	2 *Acartia clausi.*	*Acartia* tolerably common in tow-net.

Post-larval Gurnard.

1 Red Wharf Bay, 15.6.06.	8	No food in alimentary canal.	—

Post-larval Weever.

1 off Kilan Head, Cardigan,	5	1 *Paracalanus parvus.*	*Paracalanus* not present in the plankton.
1 ,, 12.7.06.	5	3 ,,	
1 Red Wharf Bay, 7.9.06.	12	1 *Temora longicornis.* 12 *Paracalanus parvus.* 14 *Isias clavipes.*	*Paracalanus* only present in the plankton.

Post-larval Gadoids.

1 Twenty-one miles N.W. of Piel, 20.3.06.	4	2 *Oithona similis.*	Absent from the plankton.
1 Five miles W. of Morecambe Bay Light-Ship, 7.5.06.	14	3 *Temora longicornis.* 1 *Anomalocera pattersoni.*	*Temora* only present in the plankton.
1 off New Quay Head, Cardigan, 25.5.06.	20	3 *Centropages hamatus.* 1 *Oithona similis*	*Centropages* only present in the plankton.

Post-larval Rockling.

6 off Dinas Head, 15.6.06.	14	No food.	—
2 off New Quay Head, 10.7.06.	14	No food.	—
7 off Morecambe Bay Light-Ship, 21.7.06.	16	No food.	—
1 off New Quay Head, 16.7.06.	18	10 *Acartia clausi.* 2 *Temora longicornis.*	*Acartia* tolerably common in the plankton, *Temora absent.*

Locality.	Millimetres.	Food.	Remarks.
1 off Entrance to Ribble, 18.7.06.	25	3 Larval barnacles (Cypris stage). 2 *Anomalocera pattersoni*	No larval barnacles in the plankton, *Anomalocera* scarce.
1 off New Quay Head, 19.7.06.	25	1 Larval barnacle (Cypris stage). 1 *Anomalocera pattersoni.*	No larval barnacles in the plankton, *Anomalocera* scarce.
1 off Kilan Head, 22.7.06.	30	4 Crab megalopa.	Crab megalopa very plentiful in the plankton.
1 Carnarvon Bay, 20.7.06	32	7 Crab megalopa.	Megalopa scarce in the plankton.
1 Red Wharf Bay, 7.8.06.	33	1 Crab megalopa.	Megalopa scarce in the plankton.

Post-larval Belone.

1 off New Quay Head, 10.7.06.	20	1 *Acartia clausi.* 2 *Ectinosoma normani.*	*Acartia* tolerably common in the plankton.
1 off Niarbyl, 30.7.06	22	1 *Acartia clausi.*	*Acartia* scarce in the plankton.

Post-larval Sand Eels.

55 from various parts of the territorial area	10-17	No food.	—

Post-larval Plaice.

1 Tremadoc Bay, 19.2.06.	15	No food.	—

Post-larval Dabs

9 Aberporth Bay, 16.5.06.	11	No food.	—
9 Fishguard Bay, 24.5.06.	11	No food.	—

Post-larval Soles.

1 off New Quay Head, 15.6.06.	6	No food.	—
1 off Puffin Island 28.6.06.	7·5	1 *Longipedia minor.* 1 *Ectinosoma sarsi.* 6 ,, *normani.*	Littoral Copepoda.

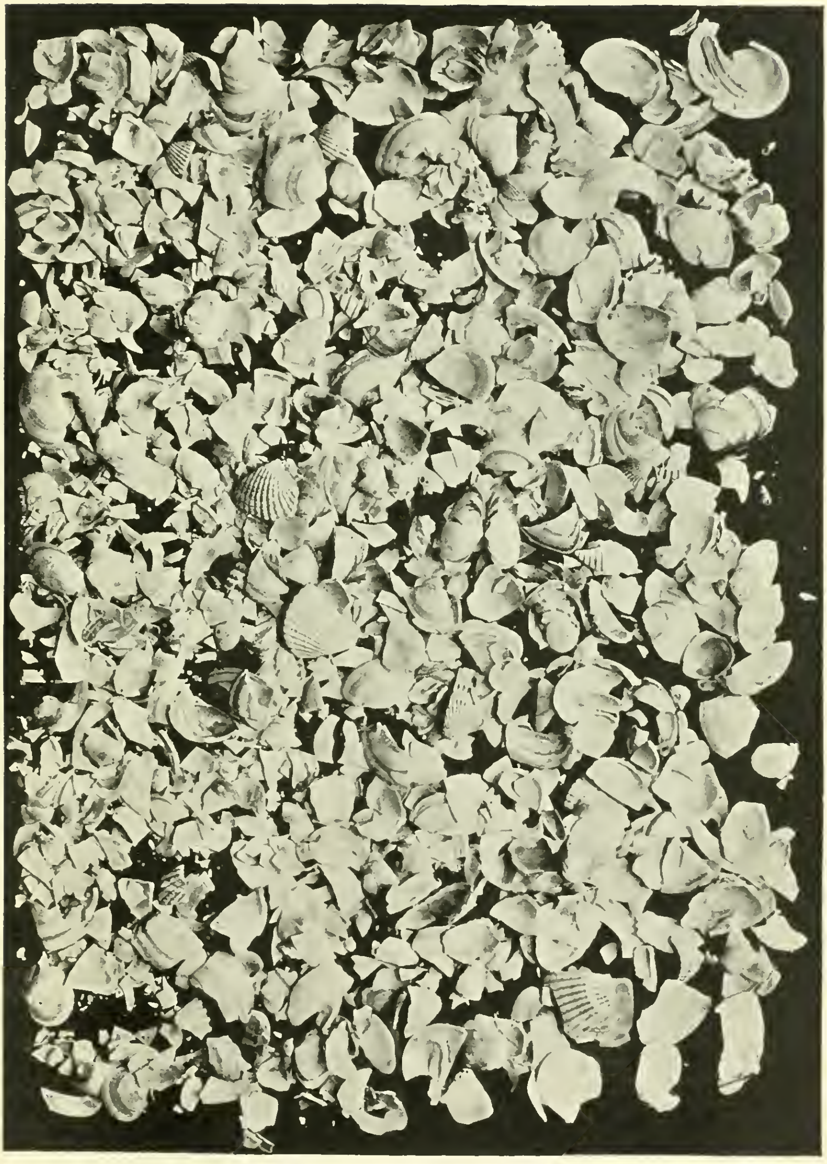
Post-larval Sprats.

Locality.	Millimetres.	Food.	Remarks.
1 off New Quay Head, 10.7.06.	15	2 *Pseudocalanus elongatus.*	*Pseudocalanus* not present in the plankton.
1 off Blackpool, 18.7.06.	15	1 *Pseudocalanus elongatus.*	*Pseudocalanus* not present in the plankton.
1 off Port Erin, 20.7.06.	16	No food.	—

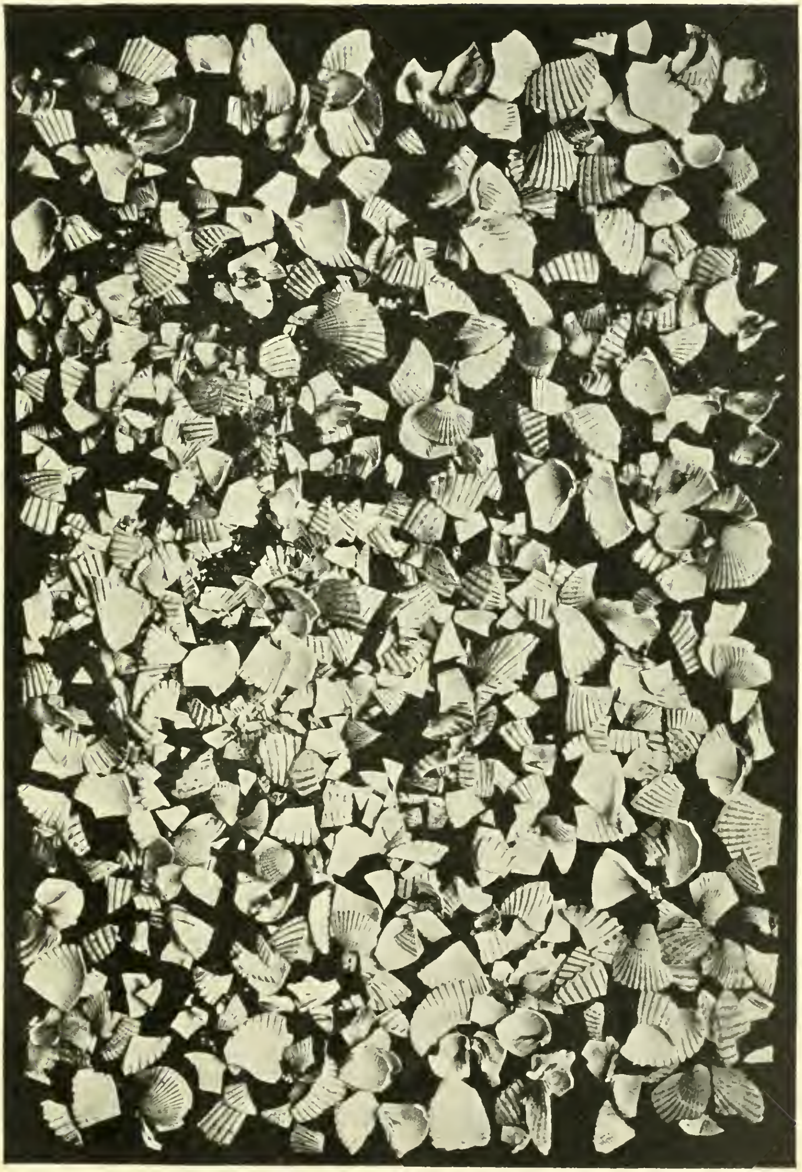
Young Pipe Fish.

Locality.	Millimetres.	Food.	Remarks.
1 Red Wharf Bay, 7.9.06	66	2 *Pseudocalanus elongatus.* 2 *Paracalanus parvus.* 6 *Acartia clausi.*	No *Pseudocalanus* in the plankton, *Paracalanus* and *Acartia* tolerably common.

The food, in all the cases where it could be recognised, consisted of crustacea, chiefly copepoda. The group was represented mainly by the pelagic forms. The few littoral representatives found indicate that the fishes containing them had been feeding near the bottom of the sea previous to capture. It evidently does not follow that if a particular copepod is any way numerous, the fish feeds entirely upon it. In the above results it will be noted that there are several instances where the fish stomachs contained copepoda not represented in the surrounding plankton taken in the tow-net along with the young fish. The fish, no doubt, in its movements through the water encounters various kinds of copepods. It is not known, however, whether it feeds indiscriminately on every one, or selects particularly coloured forms. The majority of the copepoda are more or less coloured, and so may be quite conspicuous apart from their size. It is probable that the difference between the copepods in the plankton and those in the fish stomach is due to the unequal distribution. The fish may meet with a small shoal of *Anomalocera*, young barnacles, or crab larvae, capture a few of them, and pass on. It may then reach



Contents of the stomach and intestine of a Flounder. Nat. size.



Contents of the stomach and intestine of a Plaice. Nat. size.

a part of the surface waters where the copepoda are quite different from its previous meal, and begin to feed again. In this way one would get a selection of copepods which might or might not be represented in the area tow-netted.

The following photographs show the food found in the stomachs of two of the marked fishes, when re-captured.

One is a flounder (LL86) caught on Baicliff sands, on May 26th, 1906. The food consisted mainly of *Tellina balthica*, with a few cockles, and two *Hydrobia ulvæ*. The fish weighed 272 grammes. The clean dried shells weighed 11·82 grammes (see Plate VI.).

The other is a plaice (LL78) caught on Baicliff sands on June 2nd, 1906. In this case the food consisted of cockles only. The fish weighed 221 grammes, and the clean dried shells 11·5 grammes (see Plate VII.).

Besides those illustrated we have noted the following:—LL117, caught on the Barrow sands on July 3rd, 1906. The food was mainly *Tellina balthica*, with a few *Corophium* (an isopod) and the remains of one small shore crab. LL896, flounder, caught in the Duddon, near Askam, on July 18th, 1906. The food consisted of *Tellina balthica*, and cockles, in equal quantity. A lesser sand eel caught in Ulverston Channel on May 24th, 1906, had four transforming plaice, six *Corophium* four *Mysis*, and a large number of *Gammarus* in its stomach.

PLATE VI.

Contents of stomach, etc., of flounder (LL86). Photographed natural size.

PLATE VII.

Contents of stomach, etc., of a plaice (LL78). Photographed natural size.

ARTIFICIAL FISH-HATCHING IN NORWAY.

By (I) G. M. Dannevig and (II) K. Dahl.

The name of Captain G. M. Dannevig has been associated with the artificial hatching of cod fry in Norway for many years. The utility of the distribution of such fry has been recently criticised by Dr. Hjort and Mr. K. Dahl. I have asked Captain Dannevig and Mr. Dahl to furnish me with brief accounts of recent experiments and observations, each from his own point of view; and I print these below as likely to be of interest to readers in this country.

W. A. Herdman.

I.—Letter from Captain G. M. Dannevig.

"To Prof. W. A. Herdman, F.R.S., &c., &c.

Dear Sir,

The investigations intended to solve the very much disputed question as to the utility of planting artificially-hatched cod fry in our fjords are now concluded, and from my point of view the results are extremely satisfactory.

The facts are as follows:—

The Söndeledfjord was investigated in the latter part of September in the years 1903, 1904 and 1905, and the Hellefjord in the beginning of October in the same years. Cod fry were planted in the Sóndeledfjord in the spring, 1904 and 1905, in all about 48 millions; and in the Hellefjord in the spring of 1905, about 8 millions.

The investigations as well as the planting of the fry were controlled by Dr. Hjort's assistant, Mr. K. Dahl.

The Stendalsfjord, to the westward of Lillesand, was investigated by me, and on behalf of the Nedenas County, in the first part of September, 1904, 1905 and 1906, and fry were planted in spring 1905 and 1906, in all about 16 millions. All investigations have been made with the same seine, 22 fathoms long and 4·2 metres deep in the middle. In Sóndeledfjord 106 hauls, in Hellefjord 21 and in Stendalsfjord 34 hauls. The hauls were made in the same places, almost on the same date in the different years, and as uniformly as possible. The numbers given are the entire quantities except where given as the mean of two years.

The results are:—

I.—Before Planting of Fry.

Place and Year.	Cod.	Whiting.	Pollack and Saithe.
Söndeledfjord, 1903	426	1,309	137
Hellefjord, 1903 + 1904 ÷ 2 ...	85	259	23
Stendalsfjord, 1904	454	99	131
Total	965	1,667	291

II.—After Planting of Fry.

Place and Year.	Cod.	Whiting.	Pollack and Saithe.
Söndeledfjord, 1904 + 1905 ÷ 2...	1,328	1,150	160
Hellefjord, 1905	143	180	3
Stendalsfjord, 1905 + 1906 ÷ 2...	855	230	197
Total	2,326	1,560	360

All yearlings. Only cod fry planted. Now it is incontestable that the cod have increased. The question

Total Results of Investigations.

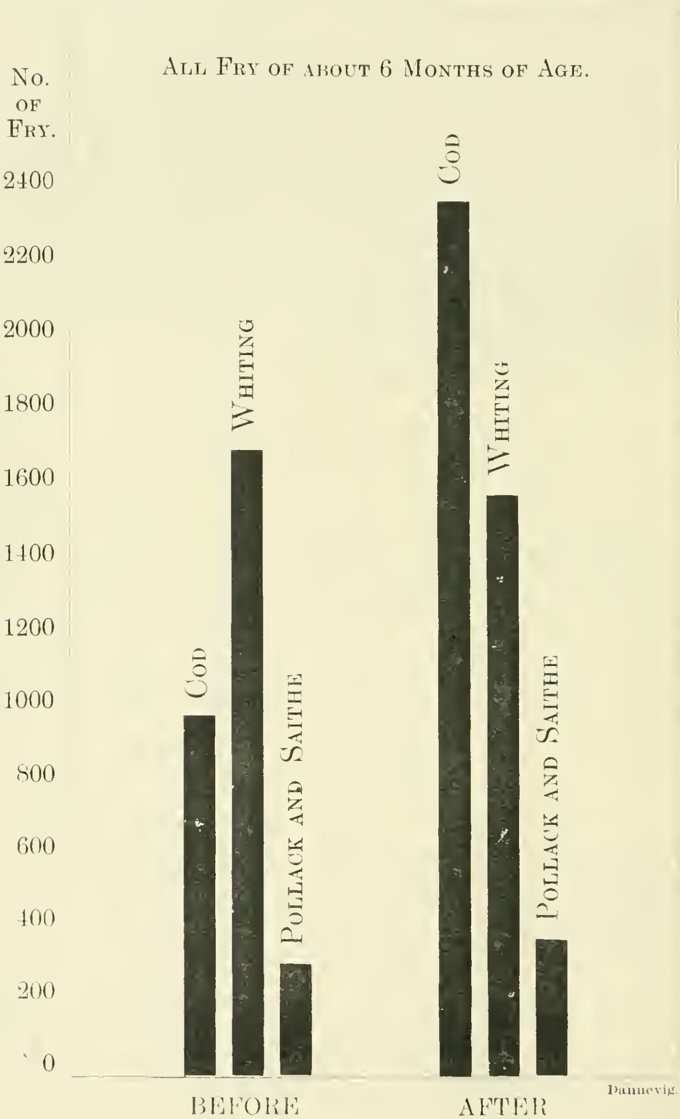


Fig. 2. Planting of Cod Fry.

is: What is the cause of the increase? I will, of course, answer: The planting of the fry. But, not so with Messrs. Hjort and Dahl. They attribute the increase to different sorts of currents, to temperature, salinity, etc., and as you will have seen from the report, Mr. Dahl goes on through one hundred pages to explain these different phenomena and their influence. Well, you will judge for yourself. I shall only add that Dr. Hjort is no friend of fish hatching, but, of course, you know all about that.

In "Report on Norwegian Fishery and Marine Investigations," pages 120-137, Dr. Hjort has put forward a series of hypotheses regarding the fisheries in our fjords, which I was bold enough to dispute, and the investigations have shown that I was right on every point.

1. It is proved that there is a great number of cod (yearlings and larger) in the fjords during the whole summer.

2. The eggs and fry don't float on the surface, but in the deeper and salter layers.

3. The surface current can't bring the eggs out of the fjords, as it only contains very few, as a rule none, of them.

4. The "local tribes" (page 135) do exist, and the proof is, that, according to Dahl, the spawning cod in the fjord have a mean length of 33 cm., while in the North Sea the spawners, according to Hjort, have a length from 55 cm. and upwards. All this, and much more, is proved by Mr. Dahl himself.

The intention of the Storthing in granting funds for the work was to find out whether the number of yearlings had increased after planting of fry from Flödevigen. My proposal that the investigations should be carried out in September, when the yearling cod was large enough to be caught in a common seine, made of netting with small

meshes, was adopted by the Storthing as well as by Dr. Hjort. This gentleman, however, thought that the manner proposed was not detailed enough to give a reliable result, and ordered Mr. K. Dahl to undertake a series of contemporary investigations regarding the currents, &c., in the Fjords. Consequently we have two different reports—one from Mr. Dahl concerning his own work, of which I know nothing, and one from me relating to our joint investigations.

The results arrived at are contrary to one another. Mr. Dahl calculates the currents, and concludes that the fry must have been carried out to sea. I have proved that the fry are in the Fjords, and Mr. Dahl has handled and measured everyone of those caught; but of this he says nothing. Mr. Swenander, who has been conducting investigations in the Trondhjemsfjord for three years, has arrived at conclusions entirely different from those of Dahl.

Dr. Hjort agrees with Mr. Dahl. He admitted, however, at the last meeting of the Fiskeriraad, that he had greatly altered his views during the last eight years, "and that he had found that he then did not know so much about fishery matters as he thought he did," but he did not say on what points his opinion was altered.

Yours truly,

G. M. DANNEVIG."

II.—*Investigations concerning the effects of liberating artificially hatched Cod Larvae in the Fiords of Southern Norway.*

By Knut Dahl.

At the request of Professor Herdman I intend, in the following pages, to give a short account of the special investigations undertaken in this country in order to understand the conditions under which we are adding hatched pelagic cod larvae to Norwegian fiords. A more detailed account has been published in Norwegian, and will probably appear later in English or German. I will here only state a few main results.

The investigations were carried out in some of the small fiords of the Skagerrak, and also on the coast and in the "Skiaergaard" outside the fiords. Captain Dannevig and I undertook, upon a plan made by him, a series of investigations in the fiords: Söndeledfiord, near Risör, and Hellefiord, near Kragerö (see Chart, fig. 3).

In these fiords the occurrence of cod fry (of the year) in the bottom stage (littoral fry) was investigated by means of a large series of hauls with a small seine (101-106 hauls in the Söndeledfiord, and 21-27 hauls in the Hellefiord). These hauls were made, as far as possible, in the same places and in the same manner. They were first made in September-October, 1903, and repeated in July-August, 1904, September-October, 1904, July-August, 1905, and September-October, 1905. The seine was 22 fathoms long, 4·20 metres deep in the middle. The mesh was about 18 meshes per foot (Norw.) on the wings of the seine. In the middle part of the seine

there was a piece, $7\frac{1}{2}$ fathoms long of a mesh of 21 meshes per foot (Norw.). In July-August a piece of "Congrès" (strong open) cloth 5·5 metres long and as deep as the seine was inserted in the middle.

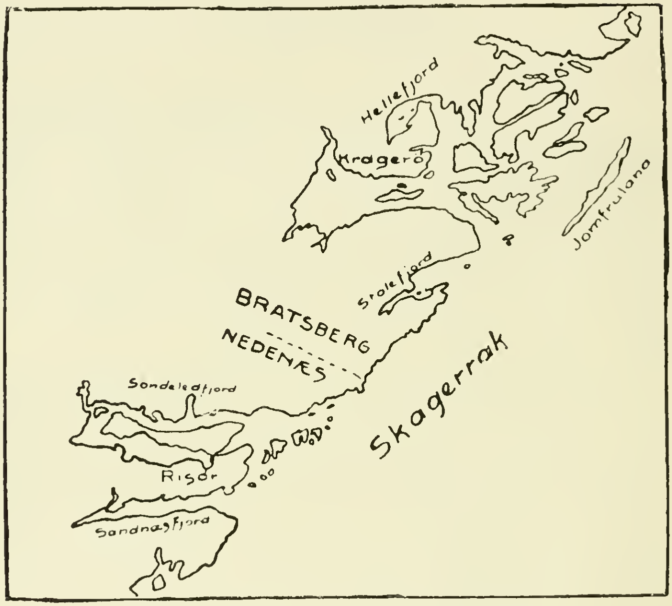


Fig. 3. General map of four fiords examined.

The fiords in question are deep fiords and the littoral fry mainly live on the relatively small shelves along the shore, in the zostera region, where the hauls with the seine were made. In 1904 about 33·5 millions of cod larvae were brought from the Flödevigen hatchery to the interior of Söndeledfiord. In 1905 33 millions of cod larvae were brought from the hatchery to the Söndeled-fiord, and 10 millions to the Hellefiord. The results of the hauls made by Mr. Dannevig and me are as follows:—

	Söndeled Fiord.		Helle Fiord.	
	Larvae liberated in the spring.	Cod fry per haul.	Larvae liberated in the spring.	Cod fry per haul.
Sept.-Oct., 1903	None	4·8	None	1·9
July-Aug., 1904	33·5 millions	33·7	None	10·9
Sept.-Oct., 1904		15·1		6·5
July-Aug., 1905	33 millions	11·4	10 millions	1·5
Sept.-Oct., 1905		11·5		7·5

It is obvious that the number of cod fry obtained per haul varies both in the different years, and also in different seasons, independently of hatching operations, to such an extent, that no safe conclusions can be drawn from the above facts alone.

Previous experience in this country had shown similar facts, and from the beginning of the work, the Fishery Board had pointed out the necessity of investigations concerning the natural spawning of the cod, the occurrence of natural larvae, the hydrography of the fiords in question, and finally the occurrence of littoral fry in the neighbouring fiords where no fry had been liberated. By order of the Board I undertook, in the years 1904 and 1905, such investigations apart from my participation in Mr. Dannevig's experiments. The occurrence of littoral cod fry was examined in the neighbouring fiords: Sandnesfiord and Stölefiord (see Chart, fig. 3). The seine employed was 38 metres long. Depth in the middle 4·5 m., in the points 1·75 m. Mesh, 16 meshes per foot (Norw.). A piece of net 5 mm. between the knots, 10·5 m. long, was inserted in the middle of the

seine. The smallest littoral cod fry could always be retained by this seine.

With this seine the Sandnes and the Stöle fiords were examined in July (respectively 10 and 7 hauls), and September-October (respectively 21 and 20 hauls). The hauls were first made in 1904 and repeated in 1905.

In the Kristianiafiord 28 hauls were made in August, 1904 and 1905. All the hauls were made as far as possible in the same places and in the same manner in both years.

The occurrence of spawning cod was studied by collecting statistics from the fishermen. The occurrence of pelagic cod eggs and larvae in the fiords and the Skagerrak was studied by making fortnightly tow-nettings in the following manner. A small motor boat dragged a circular net (1 m. diam.) of silk gauze for five minutes. The net was buoyed up so as to fish within a certain distance of the surface. In this way the net was towed 0, 2, 5, 10, 20 metres distance of the surface. The distance covered by the boat at each tow-netting was, by means of repeated experiments, proved to be about 250 metres. The occurrence of post-larval cod was studied by means of larger nets dragged for hours, and also by hand-nets.

The hydrographical changes in the Sandnesfiord the Sóndeledfiord and the Skagerrak were investigated by means of taking fortnightly traverses of the waters in question. Also direct current measurements were occasionally done with the Ekman current meter, and also with other apparatus.

These investigations have given a series of facts, which in my opinion justify the conclusion *that the adding of artificially hatched cod larvae is incapable of influencing the natural stock of fry, even in very small and limited waters, to a perceptible degree.*

At the beginning of these investigations I considered it important to study the question, whether the natural production of fry was great or insignificant in the localities in question. To this end I have from Risör gathered statistical reports on the quantity of cod caught in the Söndeledfiord.

By comparison of this material with the result of marking experiments (proportion of recaptures to number of marked fish) the conclusion may safely be drawn, that even in a small fiord like the Söndeledfiord tens of thousands of cod spawn every year, while the Flödevigen hatchery yearly manipulates the roe of about 500 cod (males and females) and distributes the hatched larvae over the whole of the Skagerrak coast. The number of spawning cod on this coast is indeed to be counted in millions.

By making uniform hauls with a tow-net (see above) I have endeavoured to study the quantitative occurrence of eggs and larvae of the cod. By these tow-nettings it was found that the eggs of the cod may occur in such numbers in the upper layers of the Söndeledfiord that up to 4,000 cod eggs may be obtained in five minutes' tow-netting. A calculation based upon the supposition that the number of eggs gathered by a series of tow-nettings in the spring, 1904, down to 10 metres in four different stations, represent approximately true values for the whole of the inner fiord, gives very large figures. Indeed, we get figures so great, that we may safely draw the conclusion, that even the interior of the Söndeledfiord, an area not exceeding five square kilometres, may in one single day contain more eggs than the Flödevigen hatchery produces in the whole season. And these quantities of eggs, the number of which may be calculated at a certain time in a fiord, are, of course, not the

whole production. Quantities are hatched previously, masses are hatched daily, and new eggs are daily spawned. Also they are distributed by the current over areas where no spawning takes place.

The natural spawning and hatching of cod eggs in the fiord is also of much longer duration than in the hatchery. Even before the fry of the hatchery are ready for planting out I have found multitudes of cod larvae in the fiords and the Skagerrak, and I have proved that cod eggs and recently-hatched cod larvae occur in the waters in limited numbers, even months after the operations at the Flödevigen hatchery have ceased.

The natural spawning and hatching of cod eggs is, therefore, in the small area, which I have investigated round Risör, of far greater dimensions than the production of larvae at Flödevigen a production which is limited to a shorter space of the season, and which is to be distributed over a large stretch of the coast.

In 1905 a series of hauls was made in order to test whether the adding of hatched cod larvae to the Söndeledfiord was capable of influencing the number of occurring larvae. A few days before the first liberation of hatched larvae took place, I made 20 hauls of five minutes' duration in four stations. The net fished on each station within 0, 2, 5, 10 and 20 metres of the surface. These hauls were repeated on three occasions during and after the period of liberation of the hatched fry.

The following tables give the dates, the total catches on each occasion, and the dates of the liberation of the different portions of larvae:—

Larvae * liberated	
Date	Millions
4/4/05	about 7
7/4/05	,, 8
10/4/05	,, 10
19/4/05	,, 8

20 Hauls each time	Cod eggs	Cod eggs last stage	Cod larvae	Size of larvae
Date				
28/3–29/3/05	1840	64	151	3–5 mm
12/4–13/4/05	2201	76	83	3·5–5 mm
29/4–2/5/05	2134	18	37	3·5–8 mm
15/5–16/5/05	1075	22	44	2–10 mm

It will be observed that the liberation of 33 millions of cod larvae produced no effect which could be recognised in the numbers caught. The totals from the hauls show that eggs were constantly spawned and hatched. *But the relation between eggs and larvae is never influenced in the favour of larvae.* For instance, notwithstanding that more than 20 millions were liberated between the first and second investigations, and that 10 millions were liberated even two days previous to the second investigation, the number of larvae constantly decreased as did the number of eggs in the last stage. On the fourth examination the number of eggs in the last stage as well as of larvae, again slightly increased.

A decrease in the number of larvae is naturally to be expected with the advancing season. But this decrease and the final slight rise is also explained by a consideration of the hydrographical changes which took place at the time of the investigations.

It will easily be understood that these small recently-hatched cod larvae which are liberated in the fiords are freely exposed to the movements of the water. During the many weeks (they rarely appear at the bottom before June-July) in which they are leading a pelagic life in

* Larvae from the Flödevigen hatchery, ready for liberation, measure (preserved in formalin, same as the captured larvae) from 3·5 to 4·5 mm.

the upper water layers, they will be largely dependent on currents. After they have grown larger they also to a very great extent take refuge under jellyfish and follow their drift.

No investigator, wishful of forming an unprejudiced opinion, can justly ignore the possibility that the eggs and young of the cod during this relatively long space of time, while they are leading a pelagic life in the waters of the sea, may, and under certain circumstances undoubtedly *must*, be subject to the movements of the waters and dependent on these as to their fate.

If we should endeavour to propagate the plants of a field with seed which floated in the air for a couple of months, surely we would have to consider the currents of the air. It is thus obvious that an understanding of the hydrographical changes in the fiords and their effects on the larvae is essential for the solution of the problem. The eggs and larvae live, according to my material, chiefly in water between 20 and 30 per thousand salinity; such as the relatively fresh surface water, which covers the salter water of the Skagerrak and fills the upper layers in the Skagerrak fiords. Eggs and larvae are distributed from about 20 metres and upwards in numbers which generally diminish towards the surface, but occur in the different depths in about the same relation to each other. Thus the larvae do not float lower than the eggs.

By experiments undertaken by Mr. Dannevig and me in the Flödevigen hatchery the recently spawned eggs and newly hatched larvae were all found to float at the surface of water of a density (*i.e.*, specific gravity *in situ*) of 1,021 and in water of less density they floated or sank in the same proportion to each other. Direct current measurements have shown that this water-layer which contains the eggs and larvae moves as well in as out of

the fiords. The upper parts of it move as a rule outwards with great speed up to 20-30 cm. per second. The lower parts of it move inwards with less speed. The depth of the outgoing current varies.

The larvae are found in the outgoing as well as in the ingoing current. The fast-flowing surface layers are not so rich in larvae as the deeper inflowing layers; but then they run much faster, and thus transfer just as great masses of larvae as the slow-flowing deeper layers that are more apt to "stow up" the larvae or pack them more closely together. Tides are in this locality of very small account, amounting only to about 10 centimetres.

Changes may occur in the above-sketched current system. A westerly gale lasting some days will thus blow nearly all the surface water away from these fiords, and bring the salt bottom water, from 20-30 metres depth, right to the surface. After such a gale the salt bottom water will again drop down and pull over it a strong, deep, ingoing water-layer from the Skagerrak. Rises and falls in the deep salt-layers of the Skagerrak will produce the same effect. A diagram showing the alterations in the water-layers contemporaneous to the tow-nettings, which I have mentioned above, will clearly illustrate the great changes which took place in the Söndeledfiord as well as also in the neighbouring fiord, the Sandnesfiord. The water-layer, in which the larvae mainly live (the white layer between 20 and 30 per thousand salinity), and where the isopykn of 1,021 is drawn, is subjected to great changes. The salt bottom water rises, sweeps all the water above 20 m. depth out of the fiord, then again drops and sucks in new water of low salinity from the Skagerrak.

Exactly the same changes occur in the Skagerrak, where contemporaneous observations were made two

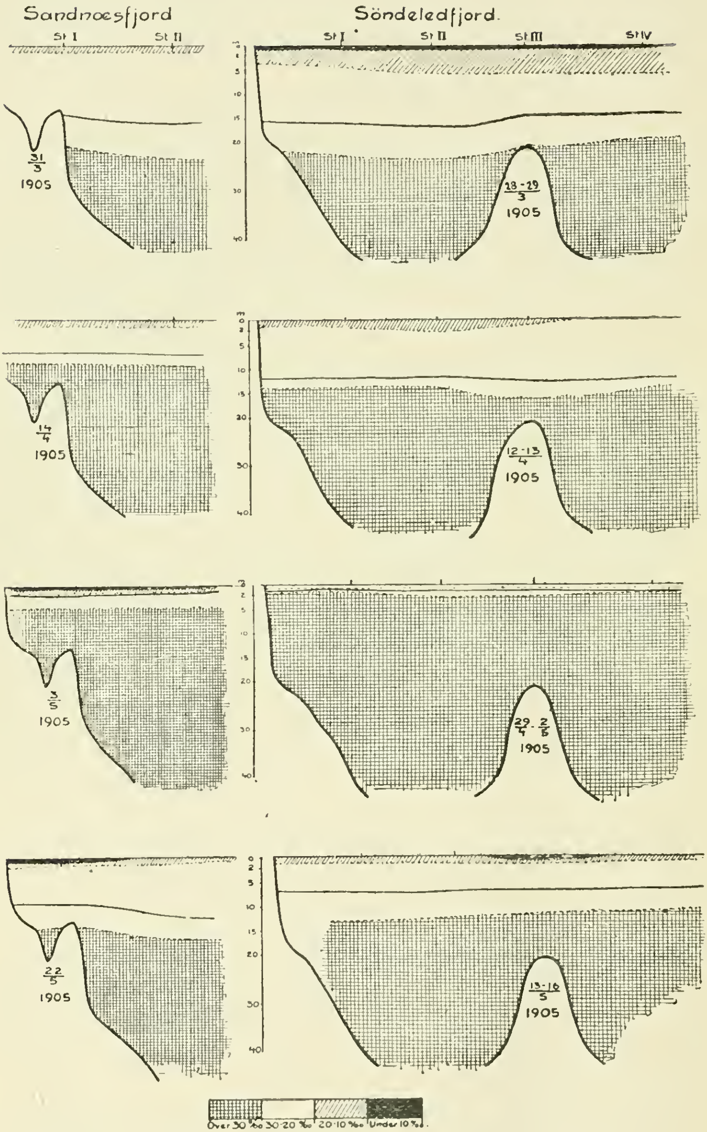


FIG. 4. Diagram showing hydrographical changes in the Sandnes and Söndeled fiords, Spring, 1905.

miles from the coast. On April 1st the isopykn of 1,021 was at a depth of 18 m.; on April 14th, at 8 m.; on May 3rd at the surface and on May 23rd at 8 m. again.

Along with these great changes of the surface layers in the fiords great changes were also observed in the

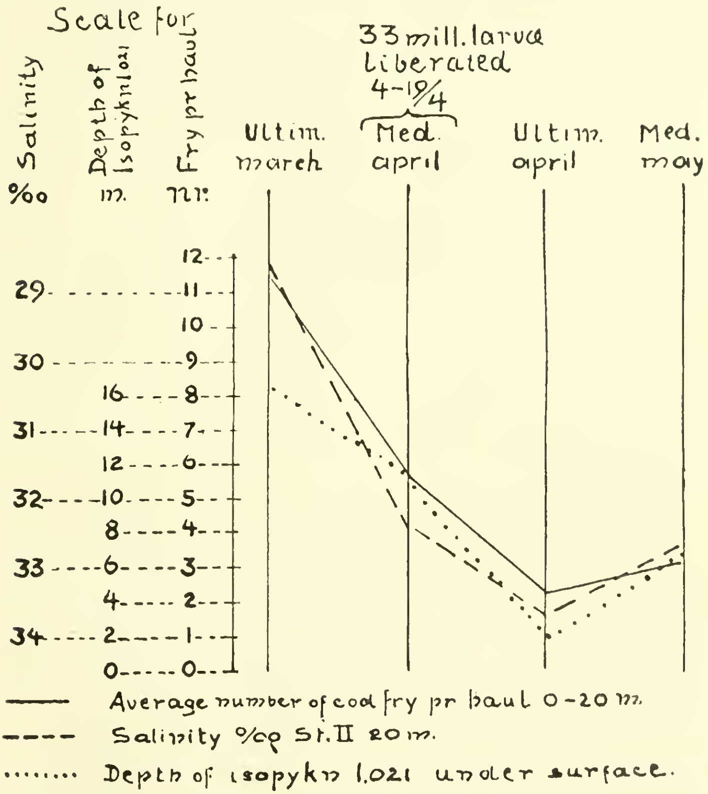


Fig 5.

number of cod larvae, as mentioned above, and also in the number of other fish larvae. The above diagram shows the relation between the rise and fall of salinity, the isopykn of 1,021 and the average number of cod larvae per haul in the Söndeledfiord on the four occasions mentioned on page 215. (See Fig. 5.)

In this diagram the four vertical lines denote the four dates of the investigation. The unbroken curve denotes the average number of cod larvae per 5-min. tow-nettings at 1 m. depth and 250 metres length, calculated by integration of the figures gained by the 20 tow-nettings, which were made on each occasion at the four stations in the fiord. The broken curve shows the alterations in salinity at 20 m. depth in the middle station. The dotted curve denotes the distance under the surface, where, on the same station, the specific gravity of the water *in situ** was 1,021, a value the importance of which has previously been mentioned.

If we study this diagram we shall observe that the decrease in the number of larvae closely follows the upheaval of the salt water and the rise of the isopykn of 1,021 towards the surface, expelling the "fry water" of lower salinity. When the salinity again was lowered and the isopykn of 1,021 again subsided the number of larvae rose.

Similar phenomena were observed also in the Sandnesfiord, and the circulation in this fiord being quicker, the alterations in the numbers of fry † were here still greater. Also a study of the occurrence of the Pleuronectid larvae shows exactly the same great decrease in their number parallel to the expulsion of the upper water-layer in which they lived.

These facts seem to me to indicate an intimate connection between the movements of the water and the movements of the eggs, larvae and fry. There is evidently a more or less constant circulation of pelagic fry connected with the circulation of the waters. The pelagic fry evidently drift in and out according to the changing

* The weight of the water in grams per c.cm.

† Also the number of eggs decreased more rapidly in this fiord.

movements of the water-masses. The pelagic cod fry may, therefore, not be considered as belonging to a certain small fiord or locality. It forms a moving and changing part of the stock of fry belonging to a far greater area of water.

As the movements of the water masses differ in different years, they would be expected to produce annual variations in the occurrence of the fry. This has, indeed, proved to be the case. In May, 1904, there was a very weak Baltic current and plenty of western water in the Skagerrak.* All the summer there were large masses of drifting fry to be *seen* in the sea and especially in the beginning of June they were very numerous. I could nearly everywhere note their presence, by direct observation, under the drifting jellyfish, and easily catch them with a small hand net. I could anchor my boat in the open Skagerrak off Risör, and observe the pelagic young of cod, haddock, and whiting in great masses drift past under the jelly-fish with a speed of 3-4 knots. The sea was quite full of jelly-fish and under nearly every one of them swam one or several young fish, which easily were caught for examination. By towing my small tow-net (1 m. diam.) for five minutes, I could catch up to 39 cod, haddock, and whiting of 2 to 3 cm. length. The "Michael Sars" found these young fish distributed in the upper layers over the whole of the deeper Skagerrak, and there can be no doubt as to these young having drifted out from shallow water, because no cod spawn in the deep Skagerrak.

In 1905 things were entirely different. This year there was a strong Baltic current.† During the early

* See Bulletin of International Council for the Study of the Sea.

† See Bulletin of the International Council for the Study of the Sea, 1904-5.

summer no young fish were, with a few exceptions, observed by me under the jelly-fish. Hauls of very great duration had to be made to prove their presence even in scanty numbers. In late summer their number seemed to increase under the jelly-fish, and in autumn the young of the whiting were for the first time to be seen in great numbers under the jelly-fish.

The investigations with seines, undertaken by Mr. Dannevig and me in common, as well as by me alone, also shewed a marked difference in the number of littoral fry obtainable in the two years. In 1904 I ascertained that the young cod 3-4 cm. long, as early as in the last days of May, occurred in the Zostera along the shores of the Söndeledfiord, the coast outside and in the Sandnesfiord. Their numbers constantly increased and they were to be found everywhere along the coast, even in the Christianiafiord, in great numbers.

In 1905 things were quite different. The facts are clearly shown by the following diagram (fig. 6), giving the average number of cod fry obtained per haul in the different fiords examined in July-August in the two years.

It is easily seen that the summer 1904 everywhere is characterised by a relative abundance of fry. The greatest abundance occurred in the open fiords Sandnesfiord and Stölefiord, which both have a lively circulation of water. Even in the Kristianiafiord, which by previous investigations (1898-99) was found to have a very poor stock of fry during summer was now relatively rich.

The summer of 1905 was characterised by great poverty.* In the Kristianiafiord the poverty was, for example, just as prominent as Hjort found by his investigations in 1898 and 1899. The Hellefiord, where 10

* The temperatures and salinities were in both years practically the same in the fiords investigated.

millions of larvae were liberated in spring, was very poor. The Söndeledfiord where 33 millions were liberated was a little richer. But the inner part of the fiord, where the majority of the fry was liberated was exceedingly poor. The greater part of the fry caught in this fiord belongs to the section of the fiord nearest to the coast and the "Skiaergaard." This part was examined a couple of weeks later than the inner part

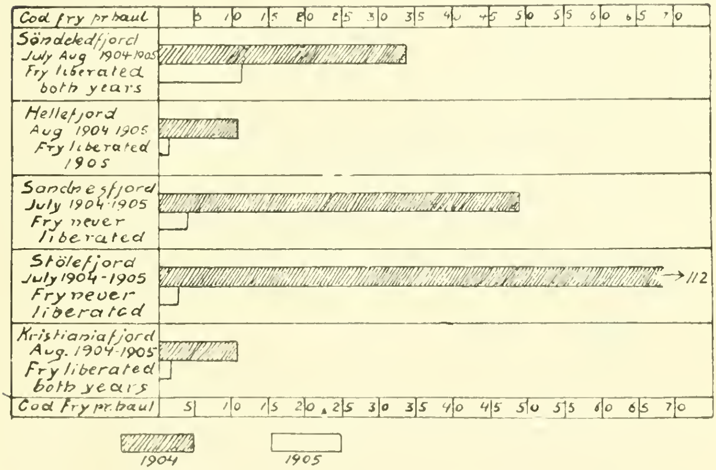


Fig. 6. Diagram showing the average number of cod fry obtained per haul with fine-meshed seines in the fiords examined, July-August.

of the fiord and about three weeks later than the Sandnes and Stole fiords. It can be proved that the number of fry increased during this time, because also the Sandnesfiord early in September was much richer in fry than it was in July. A similar diagram (fig. 7) showing the results for September-October will show this still more clearly.

A comparison with fig. 6 will immediately show

that the number of fry had largely increased in the Sandnesfiord as well as the Stölefiord.*

These diagrams indicate the conclusion that when *there is a scarcity of fry, this scarcity is common to a large stretch of coast, and when there is an abundance of fry, this abundance may be observed everywhere within a certain large*

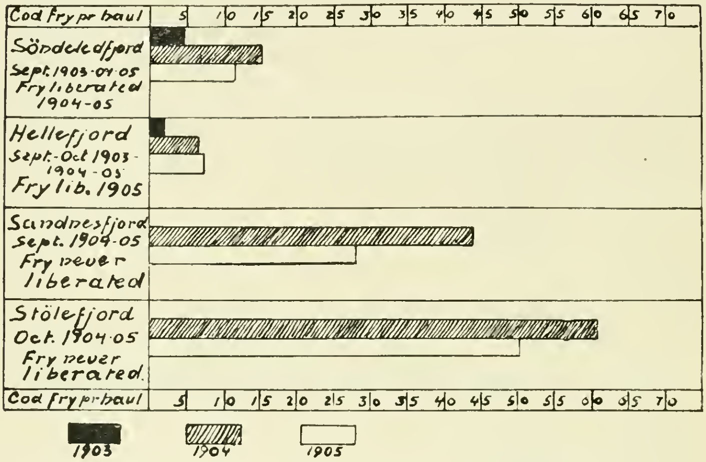


FIG. 7. Diagram showing average number of cod fry obtained per haul with fine-meshed seines in fiords examined, Sept.-Oct.

area. The addition of artificially hatched cod larvae to a locality seems nowhere to influence the relative abundance of littoral fry in a recognisable degree.

These facts, of which I have here briefly drawn the main outlines, seem to me to leave little hope as to the possibility of carrying out a fish culture, or locally

* The investigations in Sept.-Oct. in the Söndeledfiord and in the Hellefiord were made with a more coarse-meshed seine than mine. This seine (Mr. Dannevig's seine, see page 111) must have let nearly all the very small fry (under 6-7 cm.) pass through the meshes, the cloth in the middle being then removed In July-August the seines fish about alike. The results from autumn may thus in these two fiords not *directly* be compared to the autumn results in the Sandnes and Stöle fiords. Both of these were examined with my seine, which could catch all sizes.

influencing the number of littoral fry by means of liberating artificially hatched cod larvae.

An exact proof is, of course, impossible to give, as it is impossible to follow and recognise the different individuals during development. A circumstantial proof or a calculation of possibilities is all we are able to attain. And our opinion of the matter must be formed on such judgment.

As I have mentioned before, my investigations have proved that the fiords themselves produce such quantities of cod eggs and larvae that the numbers which we can produce from the hatchery at a reasonable price are small in proportion to the natural production. The liberated larvae are distributed by the current and mixed with the stock of fry belonging to far greater areas. In this way its importance to the naturally existing fry is still further lowered. Our investigations of the occurrence of the littoral fry give a clear impression of this. As far as I can see the present proofs all point to the conclusion, that the natural laws and causes which determine the growth and distribution of the cod fry along the coast seem to be so powerful that the influence of the small and limited numbers of larvae which we possess the power of liberating, cannot be traced. Evidently these larvae disappear as an insignificant and unrecognisable part of the great mass of fry belonging to a larger area.

REPORT ON EXPERIMENTS WITH MARKED FISH DURING THE YEAR 1906.

By Jas. Johnstone

The experiments with marked fishes begun in 1904 were continued during 1906. It was our intention to mark 1,000 fishes during this year, but for various reasons little more than half that number were dealt with. At the beginning of the year it was suggested to me that the plaice caught in the course of the ordinary trawling experiments carried on by the "John Fell" should be marked and liberated—that is, that special cruises for the purpose of catching fish for marking experiments should not be made, but the routine trawling experiments should be utilised for this purpose. This policy was adopted, and with one or two exceptions the fish marked and liberated were caught on the ordinary trawling stations visited as a matter of routine by the "John Fell." From several points of view this method is to be recommended, but the general result has been that smaller lots of fish were liberated than was desirable. In future it would probably be better to concentrate these experiments, and spend more time on each, catching and liberating larger numbers of fish at fewer stations. Experience of the distribution and migration of plaice has convinced me that quarterly marking experiments (roughly speaking) would probably give the best results. The fish should be liberated about the end of October or beginning of November, then in February or March, then in June or July, and possibly also in September. In this way we should make the experiments correspond with the times when the fish are changing their habits.

Pressure of other work interfered at times with the experiments of 1906. It was not always an easy matter to obtain sufficient quantities of fish of suitable sizes. Then during November and December very rough weather was experienced, and some projected experiments had to be abandoned.

As in former years, I am greatly indebted for assistance in these experiments. Both Dr. Jenkins and Capt. Wignall have given every facility and displayed great forbearance during the prosecution of experiments which have, no doubt, tended to disturb the usual routine of the patrol work of the "John Fell." As in former years, the chief Fishery officers have given indispensable assistance in receiving and forwarding marked fishes handed them by fishermen. Several members of the Sea Fisheries Committee (Messrs. Harley, Dean, Houldsworth, Saycell and Garnett) have also given invaluable assistance, and several gentlemen (Mr. Robert Knox, Douglas; Mr. A. J. Rust, of the Milford Haven Committee; Mr. F. B. Rees, Milford Haven; and the Customs' officers of that port—Mr. T. Parker, Glenluce; Professor D'Arcy Thompson, Dundee; and Mr. E. W. L. Holt, of the Irish Department of Agriculture and Technical Instruction), quite unconnected with the Lancashire and Western Sea Fisheries Committee, have given every assistance.

During 1906, 683 plaice and other fishes were marked and liberated. Of this total number 88 were flounders, 38 were dabs and 13 were small brills. One large cod was also marked and liberated, but was not heard of again. No soles were dealt with, as our former experience (and that of other investigators) of marking this fish has been unfavourable. Flounders give very favourable results, and so also do brill. Dabs, on the other hand, do not

withstand the marking operations with much success. Both dabs and soles have strongly ctenoid scales. These are probably used to some extent for purposes of locomotion, and the fishes no doubt drag themselves along the sea bottom by means of their rough skin, and in so doing cause the attached label and button to chafe the flesh and cause a bad wound. Soles, and probably dabs, are also more susceptible to slight skin abrasions than plaice or flounders.

As before, it is no doubt the case that marked fishes have been caught and were not reported. I have heard of several such cases. Capt. Wright, Chief Fishery Officer at Fleetwood, reported the finding of several marked fishes, and information as to one reached me from a friend in Cairo. In most of these cases identification of the number of the label was impossible, so they are not included in the lists given in this report.

The summary table on pages 230 and 231 shews the stations of 1906, the numbers of fishes liberated and returned and the percentages of recapture. It also includes the numbers of marked fish liberated in 1904-5 which have been returned during the past year. Before discussing the experiments of 1906, the latter may be considered.

It will be most convenient for the reader if I present the results of the experiments in the form adopted by the German investigators, working under the International Fishery Investigations Scheme.

"The analyses of size of fish" give the numbers of fishes marked and liberated. Sizes were always measured to the nearest quarter of an inch.

For convenience, the headings of the columns in the tables giving particulars of the fishes returned are numbered as follows:—

1	2	3	4	5	6	7	8
No. of label	Size when liberated Inches	Place of recapture	Date when recaught	Time in the Sea Months	Size when recaught Inches	Increase in size Inches	Method of recapture

The symbols (8) denoting method of fishing by which the marked fishes were recaptured are:—ST, steam trawler; 1T, 1st class sailing trawler; 2T, 2nd class trawler (shrimper or fish trawler); TN, trammel net; SN, stake net; GN, gill net; B, baulk; T, "tees."

Sizes are given to the nearest $\frac{1}{8}$th inch. "Time in the sea" is given in months (4-weekly periods).

Further Results of the Experiments in 1904-5.

Thirty-four fishes liberated in the course of the experiments of 1904 and 1905 have been recaptured during the present year. With the exception of experiments 21 and 22, 1905 (October, Luce Bay and Formby Channel), these further results obtained do not materially modify the percentages of recaptures given in the Summary Table published in the last Annual Report.* Interesting results with reference to the migrations and rate of growth of plaice are yielded by these recaptures, but these will be referred to later in this Report. In the meantime I give the particulars with regard to the recovery of the fishes in question:—

Experiment 4, 12th November, 1904.
Station: $1\frac{1}{2}$ miles N.W. from Great Ormes Head.

1	2	3	4	5	6	7	8
L104	$8\frac{1}{4}$	N. by W. from Ballycottin island, S. coast of Ireland.	12/11/06	26	$15\frac{1}{2}$	$7\frac{1}{4}$	ST

This fish has, therefore, been exactly two years in the sea before it was recaught.

* Report for 1905 Lancashire Sea Fisheries Laboratory, 1906, pp. 108-150.

GENERAL SUMMARY:—

STATIONS AND NUMBERS OF FISHES LIBERATED AND RETURNED.

	Station where Fish Liberated.	Date.	No. Liberated.	No. Returned.	Percentage Returned.
1	Near Great Ormes Head	1/2/06	44 plaice	10	23%
			7 dabs	1	
2	Near Fleetwood	19/2/06	35 plaice	16	46%
3	Bahama Bank	20/2/06	10 plaice	4	40%
			10 flounders	3	
4	Near Puffin Island	21/2/06	8 plaice	2	25%
			5 flounders	1	
			1 cod		
5	Near Blackpool	5/3/06	18 plaice	6	33%
			12 flounders	3	
			9 brill	4	
6	Colwyn Bay	6/3/06	23 plaice	6	26%
			19 dabs	2	
			2 flounders	1	
7	Blackpool Closed Ground	30/3/06	23 plaice	2	9%
			5 dabs		
8	Outside Walney Island	31/3/06	28 plaice	8	29%
			9 flounders	4	
			5 dabs		
9	Near Piel	9/5/06	49 flounders	9	18%
10	Near Nelson Buoy	12/6/06	40 plaice	21	52%
11	Near Pwllheli	13/6/06	41 plaice	2	5%
			1 flounder		
12	Off Llanrhystyd	14/6/06	46 plaice	4	9%
			4 brill		
			1 dab		

13	Off Dinas Head	16/6/06	20 plaice	3	15%
14	Off Ynys Fach	16/6/06	16 plaice 1 dab	1	6%
15	Near Nelson Buoy	9/7/06	50 plaice	10	20%
16	Off Penkilan	12/7/06	50 plaice	2	4%
17	Red Wharf Bay	19/9/06	41 plaice	7	17%
18	Luce Bay	3/10/06	50 plaice	1	2%

Experiments of 1906: Totals to end of Dec., 1906 :—			
Plaice	543	105	19%
Flounders	88	21	24%
Brill	13	4	30%
Dabs	38	3	8%
Cod	1	0	—
Total	683	133	19%
Experiments of 1904-5 :—			
Experiments 4, 7, 10, 14, 16, 17, 20, 1904-5... Plaice...	—	11	—
Experiment 21, 1905 ,, ...	20	8*	40%
Experiment 22, 1905 ,, ...	43	19†	44%
Total fishes returned in 1906		167‡	

* Includes 1 fish returned during 1905. † Includes 3 fishes returned during 1905.
‡ See above notes.

Experiment 7, 18th November, 1904.
Station: Luce Bay.
Four fishes are to be added to the former list.*

1	2	3	4	5	6	7	8
L242	8	Off Chapelrossen, Luce Bay, 5 fathoms.	7/2/06	—	$12\frac{1}{2}$	$4\frac{1}{2}$	GN
L252	$8\frac{1}{2}$	4 miles W.N.W. from Whitehaven Pier.	28/2/06	—	10	$1\frac{1}{2}$	1T
L287	$8\frac{3}{4}$	Off Largs, Firth of Clyde	12/11/06	—	15	$6\frac{1}{4}$	2T
L288	$8\frac{3}{4}$	Off Stairhaven Harbour, Luce Bay.	4/9/06	—	$15\frac{1}{4}$	$6\frac{1}{2}$	GN

Experiment 10, 17th March, 1905.
Station: 5 miles W. from Morecambe Bay Lightship

1	2	3	4	5	6	7	8
L490	$8\frac{3}{4}$	10-12 miles S.E. from Maughold Head, 12 fathoms.	14/7/06	—	—	—	ST

Experiment 14, 6th July, 1905.
Station: 2 miles W.S.W. from Liverpool Bar Lightship.

1	2	3	4	5	6	7	8
L528	10	Caldy Island bearing N.W., 15 miles distant.	10/7/06	—	14	4	1T
L541	$8\frac{3}{4}$	10 miles W.S.W. from Smalls Light, 57 faths.	17/9/06	—	$14\frac{1}{2}$	$5\frac{3}{4}$	ST

Experiment 16, 12th July, 1905.
Station: Near Bahama Lightship.

1	2	3	4	5	6	7	8
L587	9	8 miles S.W. from Morecambe Bay Light Ship.	7/7/06	—	$10\frac{3}{4}$	$1\frac{3}{4}$	1T

Experiment 17, 13th July, 1905.
Station: Blackpool Closed Ground.

1	2	3	4	5	6	7	8
L821	7	Morecambe, opposite old Pier 3 fathoms.	30/12/05	—	—	—	2T

Experiment 20, 22nd July, 1905.
Station: 5 miles N.W. by W. from Aberystwyth.

1	2	3	4	5	6	7	8
L848	$8\frac{3}{4}$	Horse Channel, Fairway, 10 fathoms.	26/9/06	—	$12\frac{1}{8}$	$3\frac{3}{8}$	2T

Experiment 21, 13th October, 1905.
Station: Luce Bay.
Fish caught in Luce Bay.

ANALYSIS OF SIZES OF FISH LIBERATED.

Sizes (inches)	8	$9\frac{1}{2}$	10	$10\frac{1}{4}$	$10\frac{1}{2}$	$10\frac{3}{4}$	11	$11\frac{1}{4}$	12	$12\frac{1}{2}$	$12\frac{3}{4}$	13
No. of plaice	1	2	1	1	2	5	1	2	2	1	1	1

ANALYSIS OF SIZES OF FISH RETURNED.

1	2	3	4	5	6	7	8
L860	$11\frac{1}{4}$	5 miles W. from Stairhaven Harbour, Luce Bay, 7 fathoms.	31/7/06	10	14	$2\frac{3}{4}$	GN
L868	8	Off Sand Head, Luce Bay	24/8/05	1	—	—	GN
L864	$10\frac{3}{4}$	5 miles W.S.W. from Stairhaven Harbour, Luce Bay, 6 fathoms.	25/6/06	10	13	$2\frac{1}{4}$	GN
L875	$12\frac{1}{2}$	2 miles W. from Stairhaven Harbour, Luce Bay.	23/4/06	7	$12\frac{3}{4}$	$\frac{1}{4}$	GN
L865	$10\frac{3}{4}$	Probably near Maughold Head. I.O.M.	1/2/06	4	$10\frac{3}{4}$	—	ST
L870	$10\frac{1}{2}$	17 miles N.W. from Piel Gas buoy.	17/2/06	4	$10\frac{3}{4}$	$\frac{1}{4}$	1T
L876	$12\frac{3}{4}$	8 miles W. by S. from Selker Light Ship.	17/3/06	5	$13\frac{1}{4}$	$\frac{1}{2}$	ST
L871	$10\frac{3}{4}$	6 miles E. from Balbriggan, Co. Meath, Ireland.	25/7/06	10	$12\frac{3}{4}$	2	—

Experiment 21 of 1905 was made while trawling in Luce Bay for mature plaice for Piel Hatchery. Twenty fishes were liberated, and during the next twelve months eight of these were returned. Four of these were recaptured in Luce Bay itself, not far from the place of original capture. An interesting result from this experiment is that for the first time we have observed a migration from Luce Bay into the Irish Sea. Previously the fishes marked in Luce Bay were recaught in their original habitat, in the Firth of Clyde, or in the Solway, but three (Nos. L865, L870, L876) of the lot here considered were recaught in the Northern part of the Irish Sea and one (L871) on the East Coast of Ireland, which it probably reached after traversing the waters East of the Isle of Man.

Experiment 22, 26th October, 1905.
Station: Entrance to Formby Channel.
Fish caught in Rock Channel.

ANALYSIS OF SIZES OF FISH LIBERATED.

Sizes (inches)	7¾	8	8¼	8½	8¾	9	9¼	9½	9¾	10¼	10¾	12¾
No. of plaice	2	8	9	11	5	1	2	1	1	1	1	1

PARTICULARS OF FISH RETURNED.

1	2	3	4	5	6	7	8
L904	10¼	2 miles N.N.W. from Liverpool Bar Light Ship, 13 fathoms.	26/9/06	12	13½	3¼	2T
L910	8½	Rock Channel	31/10/05	1	—	—	2T
L917	8¼	N.N.W. from Liverpool Bar Light Ship, 17 faths.	12/8/06	10	10	1¾	1T
L918	8½	Off Newcome Knoll	21/11/05	1	—	—	2T
L920	9¼	Horse Channel	17/11/05	1	—	—	2T
L925	8¾	2 miles N. from Formby Channel Fairway Buoy.	2/5/06	7	9	¼	2T
L936	8¼	Rock Channel, 5 faths....	19/3/06	5	8½	¼	1T

Particulars of Fish Returned—*continued.*

1	2	3	4	5	6	7	8
L941	8	Formby Channel, near N.W. Buoy.	9/8/06	10	$9\frac{1}{4}$	$1\frac{1}{4}$	2T
L942	$8\frac{1}{4}$	12 miles N. from Liverpool Bar Light Ship, 15 fathoms.	5/8/06	10	10	$1\frac{3}{4}$	1T
L903	8	Boghole, Ribble	17/4/06	6	8	—	2T
L913	$8\frac{1}{4}$	S. side of Ribble, opposite Ansdell Buoy.	26/4/06	6	$8\frac{3}{4}$	$\frac{1}{2}$	SN
L934	8	Bog Hole, near Birkdale Gas Buoy.	1/5/06	7	$8\frac{5}{8}$	$\frac{5}{8}$	2T
L935	$8\frac{1}{2}$	Jumbo Buoy, Southport	4/3/06	5	$8\frac{1}{2}$	—	2T
L938	$7\frac{3}{4}$	Off Jumbo Buoy	27/9/06	2	$10\frac{1}{4}$	$2\frac{1}{2}$	2T
L901	$8\frac{1}{2}$	Lune, near Glasson Dock Light.	18/12/05	2	$8\frac{1}{2}$	—	2T
L939	$8\frac{1}{2}$	Roosebeek Sear, Morecambe Bay.	3/12/05	2	$8\frac{1}{2}$	—	SN
L912	$8\frac{1}{2}$	Mostyn Deep, Dee	14/12/05	2	$8\frac{1}{2}$	—	2T
L908	8	4 miles S.W. from Morecambe Bay Light Ship.	11/8/06	10	$9\frac{1}{4}$	$1\frac{1}{4}$	1T
L906	$8\frac{3}{4}$	25 miles N. from Smalls Light.	2/9/06	11	$11\frac{1}{4}$	$2\frac{1}{2}$	ST

Experiment 22 of 1905 (Chart I.) gives results which are fairly consistent with those of other experiments. If consideration be paid to the length of time that has elapsed between liberation and recapture, I think the movements of the plaice indicate winter alongshore and summer offshore migrations. Thus all the plaice (7) recaptured within the two months after liberation were found in the shallow waters in the channels and on the edges of the banks. Four have travelled towards the Cheshire shallow waters, and three towards Ribble and Morecambe Bay. Then we have a group of five fishes recovered about the fifth and sixth month after liberation in the Southport and Mersey Channels. These have probably remained there after the initial inshore migration. Finally, there is a group of six fishes which have migrated, or are migrating out from the territorial zone, and were found after seven to twelve months in relatively deep water.

Experiment 1, 1st February, 1906.

Station: Between Great Ormes Head and Conway Bar Buoy.

Fish caught in five hauls between Red Wharf Bay and N. Constable Buoy.

ANALYSIS OF SIZES OF FISH LIBERATED.

Size (inches)	7¼	7½	7¾	8	8¼	8½	8¾	9	9¼
No. of plaice	2	3	2	6	2	4	4	1	2
No. of dabs	—	1	—	1	—	—	—	1	1

Size (inches)	9½	9¾	10	10¼	10¾	11	11¾	12½	13
No. of plaice	6	1	2	3	1	2	1	1	1
No. of dabs	—	1	—	1	—	1	—	—	—

PARTICULARS OF FISH RECAUGHT.

1	2	3	4	5	6	7	8
L712	9½	4 miles N.W. from Great Ormes Head, 14 faths.	5/8/06	6	10⅛	⅝	1T
L716	10¼	Conway Bay, 5 fathoms...	13/11/06	10	13¼	3	1T
L721	8½	N.W. from Great Orme, 15 fathoms.	30/9/06	8	11¼	2¾	1T
L733	8	Off Great Ormes Head ...	13/8/06	7	8⅞	⅜	1T
L747	9 Dab	2 miles W. from Great Orme, 5 fathoms.	3/5/06	4	9⅛	⅛	1T
L734	8¾	N.N.W. from Liverpool Bar Light Ship, 17 fathoms.	12/8/06	7	10⅝	1⅞	1T
L713	9½	1 mile S.W. from Nelson Buoy.	21/9/06	8	11½	2	2T
L728	8½	Near Bar Buoy, Ribble...	20/3/06	2	8½	—	2T
L702	10¼	7 miles S.W. from Morecambe Bay Light Ship.	14/7/06	6	12⅛	1⅞	1T
L709	9¾	Holyhead Harbour, 5 fathoms.	19/4/06	3	10½	¾	'Set net'
L726	10	Off Llanon, Cardigan Bay	10/7/06	6	10¼	¼	—

No decided conclusion can be drawn from the results of this experiment. It will be seen from the results, which are represented on Chart II., that four of the fishes returned have travelled to the North. Six were found in

the Red Wharf Bay area, while two have gone to the Western District, one being found in Holyhead Outer Harbour, and one off Llanon in Cardigan Bay.

Experiment 2, 19th February, 1906.

Station: Near No. 1 Buoy, Entrance to Wyre, Fleetwood.

Fish caught in Rivers Lune and Wyre.

ANALYSIS OF SIZES OF FISH LIBERATED.

Size (inches)	8	8¼	8½	8¾	9	9½	9¾	10	10¼	10½	11	11¼
No. of plaice	5	6	2	4	4	2	1	1	4	1	3	2

PARTICULARS OF FISH RECAUGHT.

1	2	3	4	5	6	7	8
L758	10¼	Pilling Sands	28/2/06	1	10¼	—	Tees
L763	9	Pilling Sands	20/4/06	2	9½	½	SN
L772	8¾	S. side of Lune, near No. 5 Buoy.	11/4/06	2	9	¼	SN
L774	8½	Below Morecambe, W. end Pier.	23/3/06	1	9¼	¾	2T
L775	8¼	Lune, near No. 4 Buoy...	7/4/06	2	8½	¼	2T
L785	8	Pilling Sands	26/5/06	3	—	—	SN
L755	11	1 mile N.W. from St. Anne's Pier.	7/3/06	1	11	—	2T
L756	11¼	16 miles N.N.W. from Liverpool Bar Light Ship.	1/7/06	5	13⅝	2⅜	1T
L777	8¼	12 miles N. from Liverpool Bar Light Ship, 15 fathoms.	5/8/06	6	10⅞	2⅝	1T
L781	8½	10 miles N.N.W. from Liverpool Bar Light Ship, 13 fathoms.	1/9/06	7	10½	2	1T
L783	8	Near Formby beach mark	28/3/06	1	8	—	2T
L761	9½	4 miles S. from Bahama Light Ship.	7/12/06	10	12¾	3¾	1T
L766	9	4 miles S. from Morecambe Bay Light Ship, 18 fathoms.	1/7/06	5	10¾	1¾	1T
L754	11	Between Barrels and Saltees Light Ships.	18/4/06	2	11	—	ST
L762	8¾	North Bay, Co. Wexford, Ireland, 3½ fathoms.	28/11/06	10	11⅞	3⅛	—
L780	8¼	—	4/12/06	10	10⅞	2⅝	ST
L782	8	—	4/12/06	10	11	3	ST

Experiment 2 shows again the decided contrast between the winter alongshore and the summer offshore migrations. The results are shewn on Chart II. by black circles. Remembering that the lines connect the station of liberation with the points of recapture of the fishes, we see that the fishes recaught fall into two well-marked groups—(1) a group of eight fishes recaught within the first three months after liberation, that is before the end of May, and (2) a group of five fishes recaptured from five to ten months afterwards. The former fishes were all recaught in the shallow waters in Morecambe Bay and in the Ribble and Mersey Estuaries by stake-nets, "tees" and second class trawlers; while the latter fishes were recaptured in relatively deep and distinctively offshore waters by first class vessels. It must be pointed out that the straight lines and arrow-heads do not in this latter case represent the actual paths followed by these fishes. Probably *all* those liberated immediately moved into inshore waters, where some were caught, and then after a sojourn there of two or three months the remnant migrated offshore, where a further proportion were recaptured. Two recaptures are not shewn in the chart. One of the fishes was found off the coast of Wexford, in Ireland, and the other on the South Coast of Ireland. This latter fish had in two months made a migration of, at the very least, 170 nautical miles. Two other fishes were caught offshore (by steam trawlers) after ten months, but the exact locality cannot be traced.

Experiment 3, 20th February, 1906.

Station: Bahama Bank.

Fish caught on "shoals" and in "Hole."

Analysis of Sizes of Fish Liberated.

Sizes (inches)	$9\frac{1}{4}$	$9\frac{3}{4}$	10	$10\frac{1}{4}$	$10\frac{1}{2}$	$10\frac{3}{4}$	11	$11\frac{1}{2}$	$11\frac{3}{4}$
No. of plaice	—	1	3	2	2	—	1	—	1
No. of flounders	1	1	1	2	1	2	1	1	—

Particulars of Fish Returned.

1	2	3	4	5	6	7	8
L894	$10\frac{1}{4}$ Flounder	Silverdale Sands	20/5/06	3	—	—	SN
L896	11 Flounder	Foxfield, River Duddon...	19/7/06	5	$11\frac{3}{8}$	$\frac{3}{8}$	B
L880	10	10 to 12 miles S.E. from Maughold Head, 12 fathoms.	26/7/06	5	$12\frac{1}{4}$	$2\frac{1}{4}$	ST
L882	10	Fish Market, Blackburn...	3/4/06	2	10	—	—
L883	$8\frac{1}{4}$	Fish Market, Blackburn...	5/6/06	4	$10\frac{5}{8}$	$2\frac{3}{8}$	—
L888	$11\frac{3}{4}$	8 miles S.W. by W. from Selker Light Ship.	19/3/06	1	12	$\frac{1}{4}$	ST
L891	10 Flounder	5 miles S.E. from Bahama Light Ship.	24/2/06	1	10	—	ST

Experiment 3 gives no useful results. It will be noticed (see Chart II., circles with a horizontal line) that two of the flounders originally caught in Manx offshore waters were recaptured in the Duddon and in Morecambe Bay. The plaice recaptured were all found in offshore waters. Two of these latter fishes could not be traced with certainty.

Experiment 4, 21st February, 1906.
Station: $\frac{1}{2}$ mile N.W. from Puffin Island.
Fish caught on Bahama Bank.

Analysis of Sizes of Fish Liberated.

Size (inches)	9	$10\frac{1}{4}$	$10\frac{1}{2}$	$10\frac{3}{4}$	$11\frac{1}{4}$	$11\frac{1}{2}$	$11\frac{3}{4}$	12	$12\frac{3}{4}$	$13\frac{1}{2}$	15	26
No. of plaice	1	1	1	1	—	1	1	1	1	—	—	—
No. of flounders	1	—	—	—	—	1	—	—	1	1	1	—
No. of cod	—	—	—	—	—	—	—	—	—	—	—	1

Particulars of Fish Returned.

1	2	3	4	5	6	7	8
L794	$11\frac{3}{4}$	8 miles S.W. by W. from Selker Light Ship.	19/3/06	4	12	$\frac{1}{4}$	ST
L792	$11\frac{1}{2}$	4 miles N.E. from Cardy Rocks, Balbriggan, Ireland.	27/4/06	2	—	—	—
L788	$11\frac{1}{4}$ Flounder	Off Connah's Quay, Dee...	12/7/06	5	$11\frac{1}{2}$	$\frac{1}{4}$	TN

The fishes liberated in this experiment were a few which had been kept on board the "John Fell" while making a passage from Isle of Man to Red Wharf Bay. They were caught on Bahama Bank and liberated off Puffin Island. The number of recaptures is too small to enable any conclusion to be made.

Experiment 5, 5th March, 1906.

Station: 7 miles W.N.W. from Blackpool North Pier.

Fish caught in Rivers Lune and Wyre.

Analysis of Sizes of Fish Liberated.

Sizes (inches) ...	8	$8\frac{1}{4}$	$8\frac{3}{4}$	9	$9\frac{1}{4}$	$9\frac{1}{2}$	$9\frac{3}{4}$	10	$10\frac{1}{4}$	$10\frac{3}{4}$	11	13	$13\frac{1}{2}$
No. of plaice ...	3	2	5	2	1	1	2	—	2	—	—	—	—
No. of flounders	1	—	—	2	—	3	—	—	1	1	1	2	1
No. of brill	—	—	—	1	—	1	2	1	3	1	—	—	—

Particulars of Fish Returned.

1	2	3	4	5	6	7	8
L956	$8\frac{3}{4}$	Near W. end Pier, Morecambe.	16/4/06	2	$8\frac{3}{4}$	—	B
L966	9 Flounder	1 mile below Humphrey Head.	15/6/06	3	$10\frac{1}{4}$	$1\frac{1}{4}$	B
L975	8 Flounder	Pilling Sands	26/5/06	3	—	—	SN
L979	$9\frac{1}{2}$ Flounder	Lune, Cockerham Bank	12/6/06	4	$10\frac{1}{2}$	1	—
L981	10 Brill	Sunderland Bank	16/5/06	3	—	—	SN
L962	$10\frac{1}{4}$ Brill	Pinfold Channel, Ribble...	18/4/06	2	$10\frac{1}{4}$	—	2T
L944	$10\frac{1}{4}$	8 miles N. from Liverpool Bar Light Ship.	11/7/06	5	12	$1\frac{3}{4}$	1T
L958	$10\frac{3}{4}$ Brill	Liverpool Bay, 16 faths....	9/8/06	6	$13\frac{1}{2}$	$2\frac{3}{4}$	1T
L968	9	10 miles N.N.W. from Liverpool Bar Light Ship, 10 fathoms.	24/8/06	6	12	3	1T
L945	$8\frac{3}{4}$	Probably near Morecambe Bay Light Ship.	1/9/06	6	—	—	—
L946	$10\frac{1}{4}$	S.W. from Morecambe Bay Light Ship, 25 fathoms.	30/8/06	6	$12\frac{3}{8}$	$2\frac{1}{8}$	1T
L960	$10\frac{1}{4}$ Brill	12 to 14 miles S.E. from Maughold Head, 12 fathoms.	7/8/06	6	$12\frac{1}{8}$	$1\frac{7}{8}$	ST
L964	$8\frac{3}{4}$	15 miles W. from Blackpool, 21 fathoms.	25/7/06	5	$11\frac{1}{8}$	$2\frac{3}{8}$	1T

Experiment 7, 30th March, 1906.

Station: Blackpool Closed Ground.

Fish mostly caught in Luce Bay and kept in Piel tanks during winter.

Analysis of Sizes of Fish Liberated.

Sizes (inches)	$7\frac{1}{4}$	$7\frac{1}{2}$	8	$8\frac{1}{4}$	9	$9\frac{1}{4}$	$9\frac{3}{4}$	10
No. of plaice	1	1	1	1	1	5	2	2
No. of dabs	—	—	—	1	—	—	1	—

Sizes (inches)	$10\frac{1}{4}$	$10\frac{1}{2}$	$11\frac{1}{2}$	$12\frac{1}{4}$	$14\frac{1}{2}$	$14\frac{3}{4}$	15	$15\frac{3}{4}$
No. of plaice	—	3	1	1	1	1	1	1
No. of dabs	1	2	—	—	—	—	—	—

PARTICULARS OF FISH RETURNED.

1	2	3	4	5	6	7	8
LL47	$10\frac{1}{2}$	Birkdale shore	11/6/06	2	—	—	SN
LL67	$14\frac{3}{4}$	14 miles S.E. from Douglas	18/4/06	1	15	$\frac{1}{4}$	ST

Experiments 5 and 7 may be considered together. Experiment 5 was made with fish which were caught in Morecambe Bay, in the Lune and Wyre Estuaries. They were liberated off Blackpool Closed Ground, a closely adjacent area. Experiment 7 was made with a number of plaice and dabs which had been kept at Piel Hatchery during the previous winter. It is the custom to turn these fish out in Barrow Channel at the end of the spawning season, and we thought it might be useful to mark and liberate some of these fish. Only two out of twenty-eight fishes liberated have been returned (see Chart III., circles with superposed crosses). Probably the cause of this poor result is that the fish were possessed of little vitality, and the operation of marking was fatal to most of them.

Experiment 5, however, gives the usual result. Two groups of fishes may be distinguished (Chart III., circles)—(1) six fishes which travelled into Morecambe Bay and the Ribble Estuary, these were all recaptured within four months after liberation; and (2) six fishes recaptured from offshore waters five to six months after liberation. Of the fishes making the inshore migration, three were flounders and two brills. Of those making the offshore migration, probably at a later date, two were large brills and the rest were plaice.

Experiment 8, 31st March, 1906.
Station: 4 miles W. by S. from Barrow Iron Works.
Fish caught on same ground.

Analysis of Sizes of Fish Liberated.

Size (inches)	$7\frac{1}{4}$	$7\frac{1}{2}$	$7\frac{3}{4}$	8	$8\frac{1}{4}$	$8\frac{1}{2}$	9	$9\frac{1}{4}$
No. of plaice	1	4	6	2	3	3	2	1
No. of flounders	—	1	—	—	1	1	1	—
No. of dabs	—	—	1	—	1	1	1	—

Size (inches)	$9\frac{1}{2}$	$9\frac{3}{4}$	10	$10\frac{1}{2}$	$11\frac{1}{4}$	$11\frac{3}{4}$	$13\frac{3}{4}$
No. of plaice	2	2	1	—	—	—	—
No. of flounders	1	1	—	1	1	—	1
No. of dabs	1	—	—	—	—	—	—

Particulars of Fish Returned.

1	2	3	4	5	6	7	8
LL76	$9\frac{3}{4}$	Bardsea Sands, Morecambe Bay.	19/4/06	1	$9\frac{3}{4}$	—	SN
LL78	$9\frac{1}{2}$	Baycliff Sands, Morecambe Bay.	2/6/06	2	$10\frac{3}{4}$	$1\frac{1}{4}$	SN
LL86	$11\frac{1}{4}$ Flounder	Near Baycliff, Morecambe Bay.	25/5/06	2	$11\frac{1}{2}$	$\frac{1}{4}$	SN
LL87	$10\frac{1}{2}$ Flounder	In Leven, Morecambe Bay.	13/6/06	3	11	$\frac{1}{2}$	SN*
LL102	$7\frac{3}{4}$	Off Haverigg Sea Wall...	8/9/06	6	—	—	L†
LL106	$7\frac{1}{2}$	West Hollow, Morecambe Bay.	23/4/06	1	$7\frac{3}{4}$	$\frac{1}{4}$	SN
LL112	$7\frac{1}{2}$ Flounder	Bardsea Sands, Morecambe Bay.	30/5/06	2	8	$\frac{1}{2}$	SN
LL113	$8\frac{1}{4}$ Flounder	1 mile above Humphrey Head, Morecambe Bay.	13/6/06	3	$9\frac{1}{4}$	1	B
LL98	$8\frac{1}{4}$	Off Nelson Buoy	13/7/06	4	$9\frac{5}{8}$	$1\frac{3}{8}$	1T
LL73	$11\frac{3}{4}$	4 miles N.E. by E. from Morecambe Bay Light Ship.	27/8/06	6	13	$1\frac{1}{4}$	1T
LL100	$7\frac{3}{4}$	9 miles S.W. from Morecambe Bay Light Ship.	23/7/06	4	10	$2\frac{1}{4}$	1T
LL104	$8\frac{1}{2}$	15 miles S.E. from Maughold Head, 12 to 15 fathoms.	23/11/06	9	$10\frac{3}{4}$	$2\frac{1}{4}$	ST

* Salmon Net. † Line.

Experiment 9, 9th May, 1906.

Station: 3 miles S. from Piel Gas Buoy.

Fish taken from Piel tanks, originally caught in Barrow Channel.

ANALYSIS OF SIZES OF FISH LIBERATED.

Size (inches) ...	$8\frac{1}{4}$	$8\frac{1}{2}$	$8\frac{3}{4}$	9	$9\frac{1}{4}$	$9\frac{1}{2}$	$9\frac{3}{4}$	10	$10\frac{1}{4}$	$10\frac{1}{2}$	11	$11\frac{1}{2}$	$12\frac{1}{4}$
No. of flounders	3	2	7	4	2	8	6	5	5	3	2	1	1

PARTICULARS OF FISH RETURNED—ALL FLOUNDERS.

1	2	3	4	5	6	7	8
LL117	9	Barrow Channel	8/06	3	9	—	SN
LL118	9	$1\frac{1}{2}$ miles below Humphrey Head.	26/5/06	1	$9\frac{1}{2}$	$\frac{1}{2}$	SN
LL123	$9\frac{1}{4}$	Kirby Pool, Duddon......	11/6/06	1	$9\frac{1}{2}$	$\frac{1}{4}$	SN
LL131	$9\frac{1}{2}$	Baycliff Sands	14/5/06	1	$9\frac{3}{4}$	$\frac{1}{4}$	SN
LL135	$12\frac{1}{4}$	Near Millom Pier, Duddon.	18/6/06	1	$12\frac{1}{4}$	—	B
LL142	$9\frac{1}{2}$	Baycliff Sands	11/5/06	1	$9\frac{1}{2}$	—	SN
LL152	$8\frac{1}{2}$	Foxfield, Duddon	21/5/06	1	$9\frac{5}{8}$	$\frac{1}{8}$	B
LL154	$10\frac{1}{4}$	Foxfield, Duddon	4/6/06	1	$10\frac{3}{8}$	$\frac{1}{8}$	SN
LL157	$10\frac{1}{4}$	Bolton-le-Sands	—	—	$10\frac{1}{4}$	—	SN

Experiments 8 and 9 may be considered together. Experiment 8 was made with plaice, flounders and dabs caught off Duddon Bar and liberated in a closely adjacent place. Experiment 9 was made with part of the stock of spawning flounders kept at Piel Hatchery and liberated annually. These fish were mostly caught in Barrow Channel. They were marked in the Hatchery and liberated near the entrance to Barrow Channel.

The results of Experiment 8 (Chart III.) indicate the usual two groups of recaptures. Four plaice and four flounders travelled inshore towards Morecambe Bay and the Duddon, and six were recaptured within the first three

months after liberation. On the other hand, five (four plaice and one flounder) were found in offshore waters from four to nine months afterwards.

Experiment 9 (Chart III.) indicates an inshore migration of flounders in the early summer. Not only did all the recaptures of flounders taken out from Piel take place in Morecambe Bay and in the Duddon, but four flounders caught outside Walney and liberated there made the same migration. The small numbers of flounders dealt with do not justify any attempt to construct the migration paths of this fish, but evidence of an inshore movement in the late spring or early summer appears to be forthcoming. All the flounders recaptured from the last experiment were fish in very fine condition. Without exception, all were feeding greedily on Lamellibranch molluscs (*Tellina scrobicularia*, *Mactra*) when recaptured.

Experiment 6, 6th March, 1906.

Station : Colwyn Bay.

Fish caught in Colwyn Bay and in Conway Bay, two hauls.

ANALYSIS OF SIZES OF FISH LIBERATED.

Sizes (inches)	$7\frac{1}{2}$	$7\frac{3}{4}$	8	$8\frac{1}{4}$	$8\frac{1}{2}$	$8\frac{3}{4}$	9	$9\frac{1}{4}$
No. of plaice	5	4	5	4	1	—	1	1
No. of flounders	—	—	—	1	—	—	—	—
No. of dabs	—	1	—	2	2	4	2	2

Sizes (inches)	$9\frac{1}{2}$	$9\frac{3}{4}$	10	$10\frac{1}{4}$	$10\frac{1}{2}$	$10\frac{3}{4}$	11	$11\frac{1}{4}$
No. of plaice	—	1	—	—	1	—	—	—
No. of flounders	—	—	1	—	—	—	—	—
No. of dabs	1	—	1	1	—	1	1	1

Particulars of Fish Returned.

1	2	3	4	5	6	7	8
LL20	$7\frac{3}{4}$	7 miles N.W. from Great Orme.	5/11/06	9	$8\frac{3}{4}$	1	1T
LL29	$7\frac{1}{2}$	Off Great Ormes Head..	9/12/06	10	$8\frac{1}{2}$	1	1T
LL22	$7\frac{3}{4}$	Near Cordy Buoy, Dee...	22/3/06	1	—	—	2T
LL5	9 Dab	Horse Channel, 10 faths.	13/8/06	6	9	—	1T
LL11	$8\frac{3}{4}$ Dab	Rock Channel, 3 faths....	11/8/06	6	9	$\frac{1}{4}$	2T
LL37	$7\frac{1}{2}$	Wallasey shore	26/4/06	2	$7\frac{5}{8}$	$\frac{1}{8}$	SN
LL44	$10\frac{1}{4}$ Flounder	Opposite Lytham, S. side Ribble.	19/4/06	2	$10\frac{1}{4}$	—	B
LL19	$8\frac{1}{2}$	Off old Pier, Morecambe	26/11/06	9	$9\frac{1}{4}$	$\frac{3}{4}$	2T
LL32	$8\frac{1}{4}$	South Bay, Wexford, Ireland.	16/5/06	2	$8\frac{3}{8}$	$\frac{1}{8}$	2T

This experiment did not yield very notable results. None of the dabs or flounders liberated have been recovered so far, and the movements of the plaice which were recaught do not show any uniformity.

Experiment 10, 12th June, 1906.

Station: Off Nelson Buoy.
Fish caught off Nelson Buoy.

Analysis of Sizes of Fish Liberated.

Sizes (inches)	$8\frac{1}{4}$	$8\frac{1}{2}$	$8\frac{3}{4}$	9	$9\frac{1}{4}$	$9\frac{1}{2}$	$9\frac{3}{4}$	10	$10\frac{1}{2}$	$11\frac{1}{2}$	$11\frac{3}{4}$
No. of plaice	1	5	11	5	5	4	3	2	2	1	1

Particulars of Fish Returned.

1	2	3	4	5	6	7	8
LL171	$10\frac{1}{2}$	Birkdale shore	12/6/06	1	—	—	SN
LL193	9	1 mile N.W. from Nelson Buoy, 9 fathoms.	3/9/06	3	$10\frac{3}{8}$	$1\frac{3}{8}$	2T
LL197	$8\frac{1}{2}$	1 mile S.W. from Nelson Buoy.	20/9/06	3	$9\frac{3}{4}$	$1\frac{1}{4}$	2T
LL200	$8\frac{1}{4}$	2 miles S.W. from Nelson Buoy.	12/9/06	3	$11\frac{1}{2}$	$3\frac{1}{4}$	2T
LL178	$9\frac{3}{4}$	Roosebeck, Morecambe Bay.	23/10/06	5	11	$1\frac{1}{4}$	2T
LL167	$11\frac{1}{2}$	12 miles N. from Liverpool Bar Light Ship, 14 fathoms.	15/7/06	1	$11\frac{1}{2}$	—	1T
LL169	$10\frac{1}{2}$	Liverpool Bay, 14 faths.	20/7/06	1	$11\frac{3}{4}$	$\frac{1}{4}$	1T
LL177	$9\frac{1}{2}$	Liverpool Bay, 17 faths.	26/7/06	2	$10\frac{1}{2}$	1	1T
LL180	$8\frac{3}{4}$	2 miles N.W. from Liverpool Bar Light Ship, 15 fathoms.	2/8/06	2	$9\frac{1}{2}$	$\frac{3}{4}$	1T
LL182	9	6 miles N.N.W. from Liverpool Bar Light Ship, 3 fathoms.	8/11/06	5	$11\frac{5}{8}$	$2\frac{5}{8}$	1T
LL189	9	"Meols Bay," 14 faths.	13/7/06	1	$9\frac{1}{4}$	$\frac{1}{4}$	1T
LL191	$8\frac{3}{4}$	12 miles N. from Liverpool Bar Light Ship, 14 fathoms.	16/7/06	1	—	—	1T
LL201	$9\frac{1}{2}$	20 miles N.W. from Liverpool Bar Light Ship, 19 fathoms.	30/7/06	2	$9\frac{1}{2}$	—	1T
LL166	$9\frac{1}{2}$	10 miles N.N.E. from Morecambe Bay Light Ship.	11/8/06	2	$10\frac{1}{4}$	$\frac{3}{4}$	1T
LL173	10	6 miles S.S.W. from Morecambe Bay Light Ship.	30/6/06	1	10	—	1T
LL176	$9\frac{1}{4}$	10 miles S.W. from Morecambe Bay Light Ship.	26/10/06	5	$10\frac{1}{2}$	$1\frac{1}{4}$	1T
LL181	9	7 miles S.W. from Morecambe Bay Light Ship.	2/8/06	2	10	1	1T
LL195	$8\frac{3}{4}$	6 miles N.E. from Morecambe Bay Light Ship.	11/8/06	2	9	$\frac{1}{4}$	1T
LL199	$8\frac{1}{4}$	7 miles S.W. from Morecambe Bay Light Ship.	14/7/06	1	$9\frac{5}{8}$	$\frac{7}{8}$	1T
LL202	$8\frac{3}{4}$	"Morecambe Bay," 20 fathoms.	25/7/06	1	$9\frac{5}{8}$	$\frac{7}{8}$	1T
LL203	$8\frac{3}{4}$	12 miles S.S.E. from Maughold Head, 12 fathoms.	29/11/06	6	$10\frac{7}{8}$	$2\frac{1}{8}$	ST

Experiment 15, 9th July, 1906.

Station: 5 miles N. from Liverpool Bar Lightship.

Fish caught near Nelson Buoy.

ANALYSIS OF SIZES OF FISH LIBERATED.

Sizes (inches)	$7\frac{3}{4}$	8	$8\frac{1}{4}$	$8\frac{1}{2}$	$8\frac{3}{4}$	9	$9\frac{1}{4}$	$9\frac{1}{2}$	$9\frac{3}{4}$	10	$10\frac{1}{4}$	11
No. of plaice	1	7	8	11	5	6	3	2	3	2	1	1

PARTICULARS OF FISH RETURNED.

1	2	3	4	5	6	7	8
LL254	10	7 miles (?) E. from Nelson Buoy, 7 fathoms.	29/7/06	1	10	—	1T
LL257	$9\frac{1}{4}$	Off Nelson Buoy, 9 faths.	11/9/06	2	$9\frac{3}{4}$	$\frac{1}{2}$	2T
LL260	$9\frac{1}{4}$	Off Nelson Buoy, 13 fathoms.	28/9/06	3	$10\frac{1}{2}$	$1\frac{1}{4}$	1T
LL291	$8\frac{1}{4}$	$1\frac{1}{2}$ miles S.W. from Nelson Buoy, $9\frac{1}{2}$ faths.	13/9/06	2	9	$\frac{3}{4}$	2T
LL258	$8\frac{1}{2}$	N.N.W. from Liverpool Bar Light Ship, 17 fathoms.	14/8/06	1	$8\frac{5}{8}$	$\frac{1}{8}$	1T
LL270	$8\frac{3}{4}$	Pillar Buoy, Horse Channel, 9 fathoms.	3/8/06	1	$8\frac{3}{4}$	—	2T
LL272	$8\frac{3}{4}$	Liverpool Bay, 14 faths.	24/7/06	1	$8\frac{3}{4}$	—	1T
LL277	$8\frac{1}{2}$	16 miles N.N.W. from Liverpool Bar Light Ship, 17 fathoms.	28/10/06	4	—	—	1T
LL282	$8\frac{3}{4}$	12 miles S.S.W. from Morecambe Bay Light Ship.	5/11/06	4	$10\frac{3}{4}$	2	1T
LL288	$8\frac{3}{4}$	5 miles N.E. from Liverpool N.W. Light Ship, 15 fathoms.	8/9/06	2	$9\frac{1}{4}$	$\frac{1}{2}$	1T

Both Experiments 10 and 15 have given good results, the former shewing 50 per cent. and the latter 20 per cent. of recaptures. They may conveniently be considered together, as the fish were caught on the same ground; the stations of liberation are close together, and there was only a month between dates of the two experiments.

Bearing in mind that the fishes were liberated at about the time of midsummer, we should expect to find, if the results of the experiments already discussed hold good, that an offshore migration would be exhibited. A glance at Chart IV., where the positions of recaptures are roughly plotted, will shew that these experiments do, indeed, confirm the results already obtained. Most of the fishes returned were recaptured during the three months following liberation, that is during the time when we should expect to find the offshore migration in progress. It will be seen that there is practically no alongshore or inshore migration. Only three fishes have entered the territorial waters. No. LL171, from Experiment 10, immediately on being liberated hurried off inshore, and was caught on the same day in a stake net on Birkdale shore. No. LL270, from Experiment 15, also travelled inshore, and was recaught at the entrance to Horse Channel by a second-class trawler. Finally No. LL178, from Experiment 10, went inshore, and was caught off Roosebeck by a second-class trawler. But, with these exceptions, there is a well-marked offshore migration to be observed, the majority of the fishes returned being recaught to the West of the place of liberation, Nelson Buoy. Only one, No. LL203, went far afield, and was recaught by a Douglas steam trawler S.S.E. from Maughold Head. So far as has yet been observed, none of these fishes has made the lengthy migrations of which several instances have been noticed.

Experiment 11, 13th June, 1906.

Station: Off Pwllheli beach, Tremadoc Bay.

Fish caught off Pwllheli beach and off St. Tudwall Islands.

Analysis of Sizes of Fish Liberated.

Sizes (inches)	7½	7¾	8	8¼	8½	8¾	9
No. of plaice	2	2	3	3	7	4	4
No. of flounders	—	—	—	—	—	—	—

Sizes (inches)	9¼	9¾	10	10¼	10½	10¾	11
No. of plaice	3	3	5	1	2	1	1
No. of flounders	1	—	—	—	—	—	—

Particulars of Fish Returned.

1	2	3	4	5	6	7	8
LL217	8¾	Gimlet Rock, bearing N.W., distant 7 miles, Tremadoc Bay.	19/7/06	1	9½	¾	1T
LL214	9¾	9 miles off the Bailey Light Ship, Dublin Bay, 16 fathoms.	16/10/06	5	10¾	1	—

Experiment 16, 12th July, 1906.

Station: Off Penkilan.

Fish caught off Penkilan.

Analysis of Sizes of Fish Liberated.

Sizes (inches)	7	7½	7¾	8	8¼	8½	8¾	9	9¼	9½	9¾
No. of plaice	2	1	1	7	7	9	4	9	3	6	1

1	2	3	4	5	6	7	8
LL422	9¾	2 miles S.W. from Jumbo Buoy, Ribble, 7 faths.	4/10/06	3	10½	¾	2T
LL389	8	Red Wharf Bay, 13 faths.	9/12/06	6	8½	½	1T

Experiments 11 and 16 may be considered together, since the times and stations of liberation were much the same. Neither experiment has, apparently, been successful. Last year (1905) several marked plaice were recaught in Tremadoc Bay, and it was thought desirable to fish there and mark a number of fish during the last summer. Accordingly 91 plaice caught near Pwllheli were liberated in June and July, but so far only four of these have been returned. One, No. LL217, was recaught in almost the same place where liberated, but the other three have made rather long journeys. One was caught in Dublin Bay about five months afterwards, having crossed the deep water of the Irish Channel, and two came North into Lancashire waters, one being recaught in Red Wharf Bay and the other in the Ribble Estuary. These two latter cases and another are the only instances noticed so far of plaice coming North from the Welsh Bays into Liverpool Bay, though the reverse migration has been observed many times already.

This paucity of recaptures is not to be attributed to the fact that the amount of fishing in Cardigan Bay has been less than usual. Capt. David Pritchard, the Head Bailiff at Pwllheli, writes me as follows:—"In my opinion, plaice have shifted for a time from the usual fishing ground in Tremadoc and Cardigan Bays. Our fleet of 15 small trawlers have been fishing at Tremadoc Bay and at Kilan Grounds, and only one marked plaice has been landed here. It is true that there were only two Southport trawlers in our bay last summer (1906), as against 22 the year before, but the plaice, turbot and brill were very scarce last summer (1906). There have been several large trawlers at work in Cardigan Bay during the last two months, landing their fish at Pwllheli, but a very small quantity of plaice were

landed here, and no marked ones. There has been a fair percentage of soles, but hardly any plaice to compare with former years."

I think, then, the cause of the apparent failure of these experiments is that a dispersal of the plaice present in Tremadoc Bay in June and July has taken place.

Experiment 12, 14th June, 1906.

Station: $2\frac{1}{2}$ miles off Llanrhystyd.

Fish caught from New Quay to Aberaron.

ANALYSIS OF SIZES OF FISH LIBERATED.

Sizes (inches)	$7\frac{1}{4}$	$7\frac{1}{2}$	$7\frac{3}{4}$	8	$8\frac{1}{4}$	$8\frac{1}{2}$	$8\frac{3}{4}$	9	$9\frac{1}{4}$	$9\frac{1}{2}$
No. of plaice	1	2	3	4	4	5	1	4	4	5
No. of brill	—	—	—	—	—	—	—	—	—	—
No. of dabs	—	—	—	—	—	—	—	—	—	1

Sizes (inches)	$9\frac{3}{4}$	10	$10\frac{1}{4}$	$10\frac{3}{4}$	11	$11\frac{1}{4}$	$11\frac{1}{2}$	$11\frac{3}{4}$	$12\frac{1}{2}$	$12\frac{3}{4}$
No. of plaice	5	2	1	1	2	1	1	—	—	—
No. of brill	—	—	—	—	1	—	—	—	2	1
No. of dabs	—	—	—	—	—	—	—	—	—	—

1	2	3	4	5	6	7	8
LL249	11	Off Llanrhystyd	11/9/06	3	$11\frac{1}{4}$	$\frac{1}{4}$	2T
LL329	$8\frac{1}{4}$	Between Aberystwyth and Llanon, $\frac{1}{2}$ mile from shore.	24/7/06	2	9	$\frac{3}{4}$	2T
LL335	9	Near Llanon	29/7/06	2	$9\frac{1}{4}$	$\frac{1}{4}$	2T
LL338	$7\frac{3}{4}$	Near Llanon	19/6/06	1	$7\frac{3}{4}$	—	1T

It will be seen that the plaice recovered from this experiment were all caught quite near to the place where liberated and within the territorial waters. One was recaught by the Aberystwyth first class trawler AB71, and the others by the Southport second class trawler LL343.

Experiment 14, 16th June, 1906.

Station: Ynys Fach, Cardigan Bay.
Fish caught off Aberporth Bay.

ANALYSIS OF SIZES OF FISH LIBERATED.

Size (inches)	$7\frac{1}{2}$	$7\frac{3}{4}$	8	$8\frac{1}{2}$	9	$9\frac{1}{4}$	$9\frac{3}{4}$	10	13
No. of plaice	1	2	4	1	2	1	1	3	1
No. of dabs	—	—	—	—	1	—	—	—	—

PARTICULARS OF FISH RETURNED.

1	2	3	4	5	6	7	8
LL378	$8\frac{1}{2}$	Newport Bay	17/7/06	1	$8\frac{7}{8}$	$\frac{3}{8}$	1T

Experiment 13, 16th June, 1906.

Station: 2 miles E.N.E. from Dinas Head.
Fish caught off Dinas Head.

ANALYSIS OF SIZES OF FISH LIBERATED.

Sizes (inches)	$8\frac{1}{4}$	9	$10\frac{3}{4}$	11	$11\frac{1}{4}$	12	$12\frac{1}{4}$	$12\frac{1}{2}$	$12\frac{3}{4}$	13	$13\frac{3}{4}$	14
No. of plaice	1	1	1	3	1	2	1	3	1	3	2	1

PARTICULARS OF FISH RETURNED.

1	2	3	4	5	6	7	8
LL359	12	Off New Quay Head, Cardigan Bay.	23/10/06	5	12	—	1T
LL350	$12\frac{1}{2}$	Milford Haven. Close to Milford Pier.	1/11/06	1	$13\frac{5}{8}$	$1\frac{1}{8}$	2T
LL361	$12\frac{3}{4}$	9 miles S.W. from South Bishop.	18/11/06	6	—	—	8T

Experiments 13 and 14 were made in the Milford Haven Sea Fishery District during a police visit to those

waters by the "John Fell." It was intended to carry out a somewhat extensive fish-marking experiment on this cruise, but a report of poaching by a steam trawler (which was detected) compelled Capt. Wignall to change our proposed plans.

The recaptures reported shew no unusual features. They were mostly made South of the places of liberation. Fishing there is, of course, more extensive than to the immediate North.

Experiment 17, 19th September, 1906.

Station: Red Wharf Bay.

Fish caught in Red Wharf Bay.

Analysis of Sizes of Fish Liberated.

Sizes (inches)	7	7¼	8	8¼	8½	9	9¼	9¾
No. of plaice	1	2	1	3	6	3	3	1

Sizes (inches)	10	10¼	10½	10¾	11	11¼	11¾	13½
No. of plaice	8	1	2	1	2	4	1	2

Particulars of Fish Returned.

1	2	3	4	5	6	7	8
LL439	13½	Off Great Ormes Head. 5 fathoms.	29/9/06	1	13½	—	2T
LL451	11	Red Wharf Bay, 12 faths.	11/12/06	3	11¼	¼	1T
LL454	10	Red Wharf Bay, 12 faths.	25/11/06	2	—	—	1T
LL460	10	Red Wharf Bay, 6-7 faths.	7/10/06	1	10	—	1T
LL467	8½	Red Wharf Bay, 7 faths.	7/10/06	1	8½	—	1T
LL474	8¼	Red Wharf Bay............	9/10/06	1	8¼	—	1T
LL475	8	Mostyn Deep, Dee	23/10/06	1	8¼	¼	2T
LL477	8¼	4 miles N. from Puffin Island.	23/10/06	1	8½	¼	1T

It will be seen that quite a number of recaptures were made shortly after the date of this experiment. I expected that a large proportion of these fishes would be recaught, but after the second month none has been caught. The cause is probably the wild weather of November and December, which has not only affected the fishing, but has also probably led to considerable shifting of the fishes normally present on the fishing grounds. We find that heavy gales have this effect on the shallow water fishing grounds on the West Coast of England.

Experiment 18, 3rd October, 1906.

Station: Luce Bay.
Fish caught in Luce Bay.

Analysis of Sizes of Fish Liberated.

Sizes (inches)	$8\frac{1}{2}$	$9\frac{1}{4}$	$11\frac{1}{4}$	$11\frac{1}{2}$	$11\frac{3}{4}$	12	$12\frac{1}{4}$
No. of plaice	1	1	1	1	1	5	4

Sizes (inches)	$12\frac{1}{2}$	$12\frac{3}{4}$	13	$13\frac{1}{4}$	$13\frac{1}{2}$	$13\frac{3}{4}$	14
No. of plaice	5	2	10	8	9	1	1

Particulars of Fish Caught.

1	2	3	4	5	6	7	8
LL506	$12\frac{3}{4}$	Luce Bay, off Chapel-rossen, 6 fathoms.	11 10 06	1	$12\frac{3}{4}$	—	GN

This experiment was made while trawling in Luce Bay for spawning plaice for Piel Hatchery.

Intensity of Fishing.

The Summary Table shews that about 19 per cent. of the plaice and 19 per cent. of all the fishes liberated during the year have been recovered. Of course, several of the experiments were made late in the season, and many more recaptures will doubtless be made. A considerable number of dabs were also marked and liberated, and these have given poor results. The individual experiments vary greatly in their numerical results. Experiment 10, for instance, gives 50 per cent. of returns for six months' fishing only, while Experiment 7 for nine months' fishing gives only 9 per cent. of recaptures. Many factors influence the numerical result of these fish-marking experiments. In Experiment 10 the fish had not apparently become widely dispersed, and were, moreover, liberated at a place which is situated near the widely-frequented fishing ground lying between Liverpool North-West and Morecambe Bay Lightships. Experiment 7 failed probably because the fish marked were in poor condition, and had not been able to survive the transference from tank to tank and the subsequent marking operation. Again, Experiments 11 and 16 were apparently unsuccessful because, for some reason or other, the fish marked have probably become widely dispersed, possibly into areas where there is at present little or no plaice fishing being carried on.

Premising, then, that by "Intensity of fishing" is meant only a very rough approximation to the extent to which the plaice population of the West English seaboard is being exploited, and that for even an approximate estimate of this value much more extensive marking experiments than we have made would be required, I give the figures in the last column of the Summary as representing these approximations.

Influence of Different Kinds of Fishing.

It was not always possible to obtain information as to the method of fishing by means of which the marked fishes were recaught. The following list has been compiled from the tables of particulars of fish recaught :—

Method of Fishing.	No. of Marked Fish Returned.
1st class sailing trawlers	64
2nd class sailing trawlers	37
Stake nets	23
Steam trawlers	16
Baulks	7
Gill nets	7
"Set nets," "trammels," "tees," lines, salmon nets.	5
Information not given.	8

It will be noticed that fishing by means of first class trawlers (smacks) apparently predominates in the "home grounds" of the Irish Sea. The proportions between the various methods of fishing by means of which the marked fishes have been recaught are almost exactly those compiled from the experiments of 1905.

Rate of Growth of Plaice in the Irish Sea.

In attempting to deduce the rate of growth of plaice from the marking experiments, two series of figures are made use of—(1) those indicating the increase in length of the marked fish which were set free before the beginning of the season during which growth takes place, that is April-September. The defect in this series is the small number of recaptures during the latter half of the year. It has been found during the two last years that even if a fairly large number of marked fishes have been liberated before the end of March, quite a small proportion will be recaught during the autumn and winter. One

cause is probably the decrease in the intensity of the plaice-fishery during the months of September-December. Marked plaice are usually recaught by sailing trawlers, and the unfavourable weather usually experienced during October to December is prejudicial to the fishery. It will be seen from the statistics of plaice landed in the Lancashire and Western Fisheries District that there is an undoubted falling off in the intensity of the plaice fishery during those months. Consequently, fewer marked fishes are recaught.

The following table is compiled from the results of the experiments of 1905 and 1906:—

Rate of Growth of Marked Fishes from Month to Month.

Month.	No. of Fishes Recaught.	Average Increase in Length.
January	45	0·04 inches (0·1 cm.)
February	22	0·04 ,, (0·1 cm.
March	15	0·17 ,, (0·4 cm.)
April	21	0·22 ,, (0·5 cm.)
May	27	0·53 ,, (1·34 cm.)
June	18	0·92 ,, (2·35 cm.)
July	24	1·7 ,, (4·33 cm.)
August	16	1·7 ,, (4·33 cm.)
September	13	2·44 ,, (6·12 cm.)
October	3	2·4 ,, (6·12 cm.)
November	7	2·37 ,, (6·1 cm).
December	—	— —

The results are represented graphically in Fig. 8.

It will be seen from the table and chart that the growth during January, February and March is practically *nil*. Indeed, the months October, November and December are also to be included, since a large number of the fishes included in the table for January were liberated in the preceding October and November of both years, and some were recaught during those months.

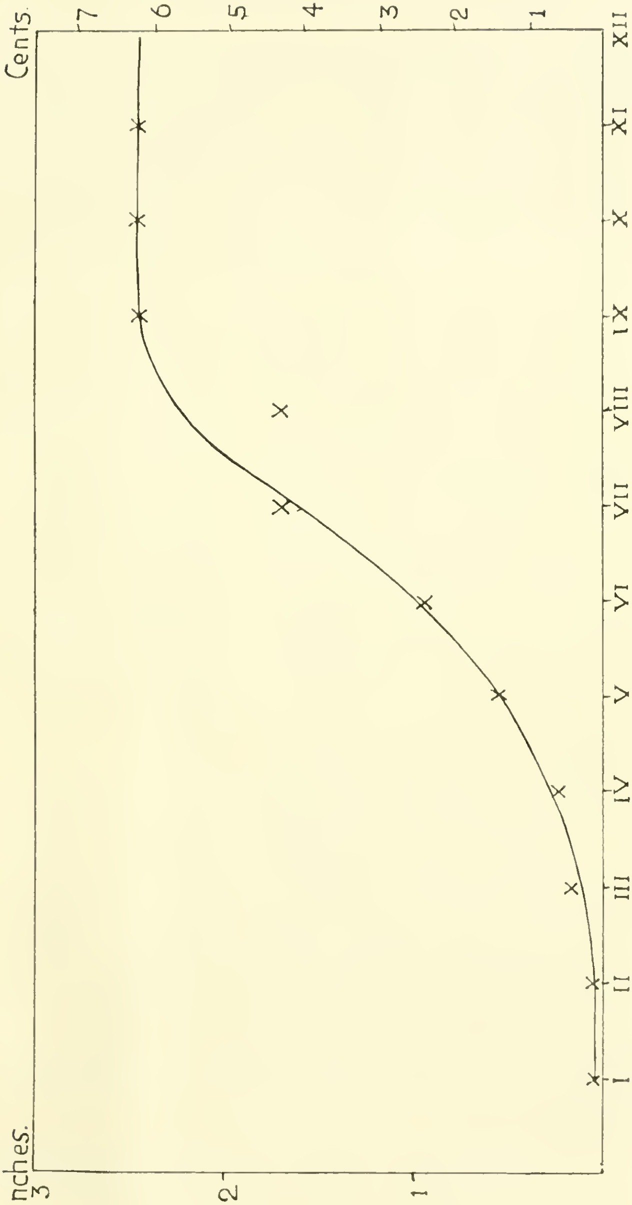


Fig. 8. Curve of growth of marked plaice.

It was only in a very few cases that any increase in length was detected in fishes liberated during October-December and recaught in January. In April the season's growth begins, and this is most rapid during the months June, July and August. It will be seen that the increase in length during August was apparently *nil*. That is the average length of the marked fishes returned during that month (and which had been in the sea during the whole season) was apparently no greater than those returned during July. I am quite certain, however, that this is only apparent, and that the fishes received in the laboratory during August were uniformly under-measured. The measurements were made by a laboratory assistant during my absence. It is, indeed, not usually a simple affair to measure a marked plaice sent by post. The fish is often dry, and has to be relaxed by immersion in water for some hours. Then a dead plaice is always shorter than a living one (probably because of the contraction or compression of the inter-vertebral discs). This can be corrected by slightly stretching the fish, and the contraction usually varies from 0·5 to 1 cm. according to the size of the fish.

It is, however, quite legitimate to "smooth" the curve, which then shows what is probably a little less than the normal rate of increase in length of plaice from month to month throughout the year. In October growth practically ceases. Plaice during the months of November-January usually have very little food in their stomachs, and many are entirely empty during December and January. During those months the weight of the fish decreases. Altogether the metabolism of the animal is greatly lessened.

The annual rate of increase in length as shewn by the curve is, therefore, about $2\frac{1}{2}$ inches. The annual

growth has, however, been measured in another way. Quite a number of marked plaice have been recovered which have experienced a whole season's growth, regarding the growth season as ending at the end of September, and the particulars of growth of these are tabulated as follows:—

PARTICULARS OF FISHES WHICH HAVE UNDERGONE ONE OR MORE COMPLETE SEASONS' GROWTH.

	Date when liberated.	Date when recaught.	Increase in size (inches).
L104	12/11/04	12/11/06	7·25 (2 seasons' growth).
L152	12/11/04	3/12/05	5·25
L242	18/11/04	7/2/06	4·5
L252	18/11/04	28/2/06	1·5
L287	18/11/04	12/11/06	6·25 (2 seasons' growth).
L288	18/11/04	4/9/06	6·5 (nearly 2 seasons' growth).
L294	18/11/04	3/10/05	1·75
L341	13/11/04	28/10/05	2·75
L345	13/11/04	3/11/05	3·5
L444	21/1/05	19/10/05	3·62
L505	17/3/05	7/12/05	2·25
L522	17/3/05	16/11/05	3·0
L528	6/7/05	10/7/06	4·0
L541	6/7/05	17/9/06	5·75 (over 1 season's growth).
L587	12/7/05	7/7/06	1·75
L713	1/2/06	21/9/06	2
L716	1/2/06	13/11/06	3·0
L721	1/2/06	30/9/06	2·75
L760	19/2/06	28/11/06	3·11
L762	19/2/06	28/11/06	2·85
L848	22/7/05	26/9/06	3·3
L904	26/10/05	26/9/06	3·25
L938	26/10/05	27/9/06	2·5
LL19	6/3/06	26/11/06	0·75
LL20	6/3/06	5/11/06	1·0
LL29	6/3/06	9/12/06	1
LL104	31/3/06	23/11/06	2·25

Average: 3·01 inches (= 7·6 cms.).

Several fishes exhibiting a complete season's growth have been received since the above table was compiled. The results do not, however, alter the general growth rate already deduced.

Twenty-seven fishes are represented, and this is

probably a sufficient number to yield a fair average. In calculating this, however, the total increase has been divided by 29 instead of 27, since two of the fishes have undergone two seasons' growth. One has slightly over one season's growth, but this may be neglected. The average thus obtained is almost exactly three inches.

This is rather more than the result given by the former table, but it must be remembered that the latter probably under-estimates the rate of growth. If a larger number of marked fishes had been recovered in September-November, the growth would no doubt have been greater. But it is also probable that the results of the second table slightly over-estimate the year's growth. The fishes represented have all been in the sea for over the average length of time between marking and recapture. They are, therefore, probably more vigorous fish than the others, and may have grown more rapidly. Their average initial length was also a little more than the others.

At any rate the difference is not great, and one may conclude that in the Irish Sea plaice grow about $2\frac{3}{4}$ inches in the year. This applies to fish which are initially of the ordinary smaller marketable sizes, viz., 8 to 10 inches.

It should be noted, too, that considerable variation in growth rate exists. Thus plaice No. LL19, after a whole season's growth, had increased only $\frac{3}{4}$-inch in length. On the other hand plaice No. L152, after a season's growth, had increased in length $5\frac{1}{4}$ inches. Both cases are of course extremes, and are quite abnormal.

The otoliths, or earstones, of about half the marked plaice recovered have been examined, with the object of determining the ages of the fishes. It is well known that the calcareous matter in these structures is laid down regularly, so that every year after the first, two distinct

rings an opaque zone and a translucent zone are added to the otolith. By counting the number of opaque rings, it it possible to arrange the fishes in the groups O, I., II., III. and IV. according to the number of these zones outside the dark nucleus of the otolith. Of the total number of marked plaice returned 66 have been examined in this way, and may be grouped as follows:—

O Group	(in the first year of life)... ...	0·
I. ,,	(,, second ,, ,,)... ...	3
II. ,,	(,, third ,, ,,)... ...	34
III. ,,	(,, fourth ,, ,,)... ...	22
IV. ,,	(,, fifth ,, ,,)... ...	12

The numbers examined are, of course, much too small to enable a satisfactory estimate of the size of the fishes at each year to be made. I give the averages calculated for what they are worth:—

Females in Group II., average length	=	9·3 inches.
,, ,, III., ,, ,,	=	12·2 ,,
,, ,, IV., ,, ,,	=	14 ,,

Fish Caught in Extra-Territorial and Intra-Territorial Waters.

There were almost exactly as many marked fish recaught outside as in the territorial waters. Such a statement possesses, however, no significance since, if it is the case that an offshore migration takes place in the summer months and an inshore and alongshore migration in the winter months, it obviously follows that the numbers of marked fishes caught inside and outside the territorial limits depends on the time of year at which most of the marked fishes were liberated. If we mean by "winter" the months October to March, and by "summer" the months April to September, we then

find that 613 plaice were liberated in the "winter" months of 1904-5, and 217 were liberated during the "summer" months. During the year 1905 about 72 per cent. of the fishes recovered were recaught within territorial waters, and about 28 per cent. were caught outside the territorial limits. Thus the result of these experiments, in which nearly three times as many fishes were liberated during the winter months as during the summer, is that nearly three times as many fish were caught within the territorial as without. On the other hand, in 1905-6, 290 plaice and flounders were liberated in the winter months and 354 plaice and flounders in the summer months, and we find that in these experiments, when the liberations during the two seasons were not far from being equal in number, the number of fishes recaught outside is very nearly equal to those recaught inside the territorial waters.

With regard to the size of the fishes recaught, these have not so far been tabulated so as to bring out any relation between depth of water and length of fish. It will be better to let these observations accumulate, and then make this analysis when quite a large number of marked fishes have been recovered. Generally speaking, fishes which at the time of marking and liberation were the largest have travelled furthest. Large fishes have, of course, more vitality, and it is undoubtedly the case (with certain well-known exceptions) that the plaice caught outside territorial waters are larger on the average than those caught inside. But as regards the proportion of fishes caught inside as compared with those caught outside the technical territorial water limit, the main factor is the opposing offshore and inshore migrations, which depend more on the seasons than on the mere size of the plaice.

General Conclusions.

1.—Percentage of fish recovered.

This, as the Summary Table shews, varies from 50 per cent. to 4 per cent. in the case of plaice, taking each experiment by itself. The causes of the difference in the percentage of fishes recorded are (1) the intensity of fishing, as for example in the case of Experiment 10, where an active fishery was carried on during the summer months over the area immediately contiguous to the place of liberation; (2) on the method of dispersal of the marked fishes, as for instance in Experiments 11 and 16, where the marked fishes liberated have probably been widely dispersed into areas where little trawl fishing is carried on; and (3) on the vitality of the marked fishes, as for instance in Experiment 5, where (as in the case of Experiment 12 of 1905) plaice were marked which had been for many months kept in tanks, and were in poor condition.

2.—Influence of methods of fishing.

First-class sailing trawlers have recaught more marked plaice than any other class of vessel or fishing method. There is little doubt that in the Lancashire and North Welsh Fishing Grounds this method of trawling predominates, at least for the "home waters." The steam trawlers have caught fewer fishes, but it is well known that these vessels go much further afield and do not frequent the grounds where the marked fishes may be expected to be recaught to the same extent that the smacks do.

3.—Rate of growth.

The estimates of the rate of growth of marked fishes constructed on the results of the experiments of 1906 agree

well with those of 1905. Plaice practically do not grow at all during the months October to March. At the end of the latter month growth begins. During the months noted, any apparent increase in size of the plaice returned is probably due as much to errors in measurement as to actual growth. At the end of March we begin to notice an increase in length, and during April, May and June the fish steadily increase in length. During July and August the growth is most rapid, and during September it begins to fall off, and in October the plaice have ceased to grow. An estimate of the rate of growth based on the study of a curve constructed from these monthly increments of growth gives us a value of about $2\frac{1}{2}$ inches (6·3 centimetres) as the yearly growth rate of the plaice in the waters of the Irish Sea East of the Isle of Man and adjoining the coasts of Lancashire, Cheshire and North Wales.

But when the increments of growth indicated by the fishes which have been recovered after one or more years' sojourn in the sea are tabulated, the average growth rate works out at almost exactly 3 inches (7·6 centimetres). A sufficient number of fishes have been recaught, after being about a year in the sea, to render this estimate a very probable one. At the same time it should be noted that these are the larger and more vigorous fishes (as is indicated by their more lengthy migrations), and that they, therefore, grow perhaps more rapidly than the others which have remained closer to their original habitats.

The cessation of growth in the colder months of the year is not necessarily connected in any way with the spawning habits of the fishes. The great majority of the marked fishes recaptured were immature fishes, and one cannot, therefore, attribute the cessation in growth in the

winter to the maturation of the reproductive organs. There is undoubtedly a decrease in the metabolism of the fish during the cold weather. It does not feed, or does so to a very slight extent, during the months of December and January, and the weight of a plaice of a certain length is always less in the winter than the weight of a fish of the same length in the summer.

4.—The migrations.

It should be noticed that many instances of quite exceptional migrations are recorded in the tables. Thus fishes liberated off the coast of Lancashire have been recaptured off the East and South Coasts of Ireland, and fishes liberated in the same area have also been recaught at the mouth of the Bristol Channel. These lengthy migrations would not surprise us if they were made by actively growing fishes like the cod or hake, or pelagic fishes like the mackerel, but one is accustomed to speak of the plaice as a semi-sedentary fish. Leaving aside these exceptional migrations, the results of this and last year's experiments shew with some probability that plaice in our waters do not move about in the winter to the same extent that they do in the summer, and that the winter migrations are mostly alongshore ones, with perhaps a general trend to the North along the coasts of Cheshire and Lancashire. In the summer, on the other hand, the migration is an offshore one. There are evidences of a tendency to the southward, and in the exceptionally lengthy migrations already referred to, it is generally this southerly migration that is made. While plaice have been observed to travel from the coasts of Lancashire and North Wales into Tremadoc and Cardigan Bays, the opposite migration has only been observed in two instances.

It should also be noted that plaice are not of necessity restricted to comparatively shallow waters. The opinion of most fishermen and others is that outside the 20-fathom contour line plaice are hardly to be found, and no doubt this is largely true. But the fish does migrate, at least, through waters of much greater depth than this, for we have found that they may cross the Irish Channel, which nowhere has a depth of less than about 50 fathoms, and one plaice (L541, Experiment 14, 1905) was actually caught by a steam trawler in water of 57 fathoms W.S.W. from the Smalls Light.

Evidence that the marking operation, if carried out carefully on a vigorous plaice, has no effects which are prejudicial to the normal movements and growth of the fish is afforded by several plaice which have been recaught after a considerable lapse of time. No. L104 was taken after exactly two years had elapsed since the time of liberation: this fish had grown $7\frac{1}{4}$ inches. No. L287, too, was recaptured after being almost exactly two years in the sea: it had grown $6\frac{1}{4}$ inches; and No. L288 was also retaken after very nearly the same interval, and was $6\frac{1}{2}$ inches larger than when marked. All these fishes passed through my hands, and their condition was that of normal well-nourished fishes, while the wound caused by the affixed mark was clean and not much larger than when initially made. Then quite a number of fishes have been returned after having been in the sea for periods of from 9 to 15 months, and with few exceptions normal rates of growth were exhibited.

Explanation of the Charts.

The charts are to be regarded as exhibiting objective representations of the migrations of the fishes. Except in Chart I it has not been attempted to express synoptically these migrations. Probably the accumulation of several years' results will enable this to be done. In the meantime it is best to indicate the facts only.

The lines connecting the stations of liberation with the places of recovery do not, of course, necessarily indicate the migration paths.

It was often difficult to be sure of the exact position of recapture. Depth of water, for instance, as given on an Admiralty chart, often does not agree with the recorded position of recapture. It is perhaps nearly always the case that there may be an error of from one to several miles in the recorded place of recapture, since a fish may be caught at any point of a haul (which may be from 2 to 24 miles in length).

INTERNAL PARASITES AND DISEASED CONDITIONS OF FISHES.

By Jas. Johnstone.

1. CESTODA.
2. TREMATODA.
3. PROTOZOA.
4. CATARRHAL CONDITIONS IN DAB AND SALMON PARR.

I.—CESTODA.

Abothrium rugosum (Goeze).

From *Gadus callarias.* This is *Bothriocephalus rugosus* (Goeze) Rudolphi = van Beneden's *Abothrium gadi.*

About a dozen large cod were dissected last winter, and this cestode was invariably found. Sometimes there were as many as a dozen large worms in each fish. The head of each cestode is implanted in a pyloric caecum, in such a manner that it is impossible to extricate it. I repeatedly dissected these structures with the greatest care, but was never able to find anything resembling a typical bothriocephaline scolex and I do not think that this structure exists in the mature stages of the worm. A portion of the anterior end of the strobila is buried up in a caecum and when the walls of the latter are picked away bit by bit with dissecting needles all that remains is a contorted, horny or waxy-looking, thick filament. The walls of the caecum undergo profound change and become semi-transparent and waxy, sometimes horny, in nature. Sometimes the anterior end of the cestode has perforated the lateral wall of the caecum and lies outside the latter as a contorted kind of cord. It is possible to pick away this investment and then the greatly con-

tracted strobila is seen inside, but without any trace of segmentation. As one attempts to dissect out the latter one finds that it gradually becomes fused with the surrounding waxy tissue which is probably derived from the caecum, and invariably the structure breaks. Von Linstow* describes the worm as having a pseudo-scolex with two slightly developed sucking grooves and figures such a head, from the intestine of *Lota vulgaris*, as a normal structure. Probably in young codling, recently infected, a stage of the cestode with such a scolex might be found but doubtless with increasing age the changes mentioned above occur, and the normal structure of the head disappears.

The lumen of the gut immediately behind the stomach may at times be almost blocked by the strobilae of these cestodes. The largest specimen found was 85 cm. in total length and about 8 mm. in breadth at its widest part. This worm was, however, incomplete. The older proglottides contained fully developed oncosphere larvae belonging to a later stage than Schauinsland's Fig. 8. (Bronn, Thier-reich, Bd. 4, 1 B, Pl. LVII, Fig. 8.) These larvae have a fully developed mantle. They are from 90 to 120 μ in diameter. The undeveloped eggs from the less ripe proglottides are much smaller, and are about 30 μ in diameter.

Echinobothrium affine, Diesing.

From *Raia clavata*, Shoals, 1906.

A single specimen of a small cestode, preserved from the contents of the spiral valve of a large thornback ray, appears to belong to this species. The worm, however, differs in certain respects from both *Echinobothrium typus* and *E. affine*. Fig. 9 represents the scolex, neck and the

* Arch. f. Naturgesch., 54 Jahrg. 1888, Bd. 1.

first few proglottides, and Fig. 11 a part of the neck with some typical spines. Measurements from this single specimen are:—

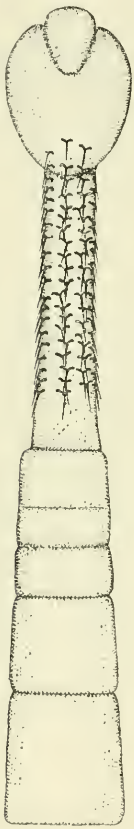


FIG. 9. *Echinobothrium affine*, Diesing. Head and part of strobila. × 44 dia.

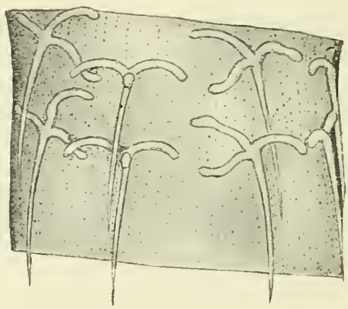


FIG. 10. *Echinobothrium affine*, Diesing. Spines on neck. × 300 dia.

Length of head: 1·3 mm.
Breadth of head: 0·36 mm.
Length of a spine from the neck: 0·1 mm.
Breadth of a spine from the neck: 0·05 mm.

A notable difference from the descriptions of either of the above specimens is the absence of coronal hooks. In both *E. typus* and *E. affine* there are two groups of long, slightly-curved hooks on the two muscular lobes of the scolex. In my specimen no trace of these was seen. I think it probable, however, that these spines, or hooks, have been lost in detaching the cestode from the walls of the intestine. Very distinct indications of a musculature which might easily serve for producing movements of the coronal spines are visible.

The neck is long and the spines there are well shown. Four longitudinal rows can be seen when the worm is slightly flattened out. These spines differ slightly, however, from the figures of van Beneden,* or Wagener.† The summit of each hook (Fig. 10) is triradiate, these transverse pieces being bent or slightly twisted. The shaft of the spine itself is very slightly curved.

Calliobothrium eschrichtii, van Beneden.

From *Mustelus vulgaris*, Llandudno Bay, 1906.

A small male *Mustelus* examined had numerous cestodes on the walls of the spiral valve. Each strobila was about 8 mm. to 1 cm. in total length and consisted of comparatively few (about half-a-dozen) proglottides. In addition to these strobilae there were very many detached proglottides in the lumen of the large bowel, most of which belonged presumably to the cestode referred to here. Measurements are:—

Length of strobila: 8 mm. to 10 mm.
Length of terminal proglottis: about 3·5 mm.
Length of first distinct proglottis: 0·6 mm.
Length of scolex: 1·2 mm.
Breadth of scolex: 1 mm.
Greatest length of hooks: 0·08 mm.

* Mem. sur lẽs Vers Intestinaux, 1858; pl. 19.

† See Bronn's Thier-reich, Bd. 4, 1 B, Taf. xl., fig. 1.

The neck is very short. The whole strobila immediately breaks up on preservation in formalin.

Fig. 11B represents the scolex and fig. 11A a pair of hooks. I find the size and appearance of the accessory

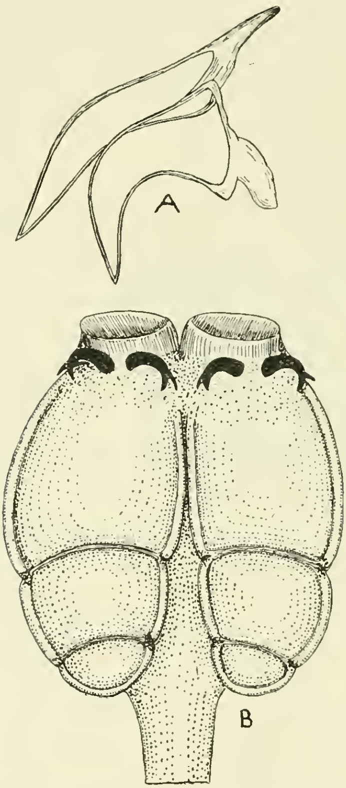


FIG. 11. *Calliobothrium eschrichtii.* A—Hooks, × 575; B—Scolex, × 45 dia.

sucker at the summit of the scolex differs somewhat from van Beneden's figure 3*, but the precise appearance of cestode worms when preserved varies so much that the

* Fauna littorale de Belgique. Vers Cestoides, pl. xix.

differences are perhaps to be attributed to the action of the preservative. The hooks are large and very noticeable. They are not bifurcated, but lie in pairs with their broad bases in close contact. One is only slightly curved, but the other is strongly bent. Delicate focussing shews that these structures are hollow.

Anthobothrium musteli, van Beneden.*

From *Mustelus vulgaris,* Llandudno Bay, 1906.

About six specimens of a cestode which appears to be the above species were found in the large intestine of a small *Mustelus.* The characters differ slightly from those

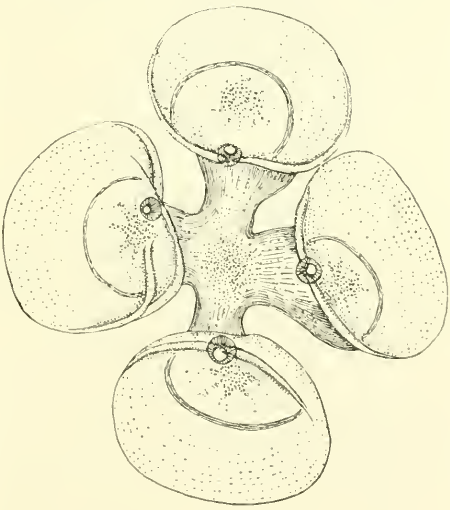


FIG. 12. *Anthobothrium musteli.* Scolex. × 46 dia.

given by van Beneden, so I add a description and figure. The measurements of the worm are:—

Length of longest strobila (incomplete): 32 mm.
Diameter of scolex: 1·3 mm.
Diameter of a bothrium: 1·3 mm.
Diameter of auxiliary sucker: 0·1 mm.
Length of a free proglottis: 6 mm.
Breadth of a free proglottis: 2·5 mm.

* Vers Cestoides, p. 126, pl. 7.

The scolex, which is represented in fig. 12 is large and very regular in shape, suggesting a four-petaled flower. There is no myzorhynchus. There are four long mobile pedicels, each of which carries a shallow cup-shaped bothrium—this is never trumpet-shaped. The internal margins of the bothria have thickened rims with a notch in the middle, but the external margins are very thin. On the internal margin of each bothrium is a small auxiliary sucker, which is not conspicuous and may easily be overlooked. In the centre of each bothrium is an irregular rosette-shaped patch, which appears to represent a radial arrangement of muscle bands, such as is represented in van Beneden's figure 3, but the precise disposition of the muscle bundles shown there does not appear in my specimens. Round this is an annular band of muscles.

Tetrarhynchus erinaceus, van Beneden.

An interesting addition to the intermediate hosts of this tapeworm is the Halibut, *Hippoglossus vulgaris.* Two specimens of pieces of halibut flesh were sent to this laboratory from the Board of Agriculture and Fisheries. In one case the flesh was abundantly infested with the plerocercoid larvae of the cestode, and in the other case a similar infection had taken place, but the larvae were restricted to the muscles round the vertebral column. The cysts containing larvae were unusually large, and were usually present in tubular cavities in the muscle tissue. Many larvae were in process of disintegration, and in some cases the cyst contained nothing but a mass of calcareous granules. Usually plerocercoid larvae of *T. erinaceus* are adherent to the peritoneum and projecting into the body cavity, and the general infection of the flesh is apparently a rare condition.

2.—TREMATODA.

Distomum ocreatum, Molin.

From stomach of *Conger vulgaris*; top end of "Hole" (nearly midway between Douglas and Fleetwood).

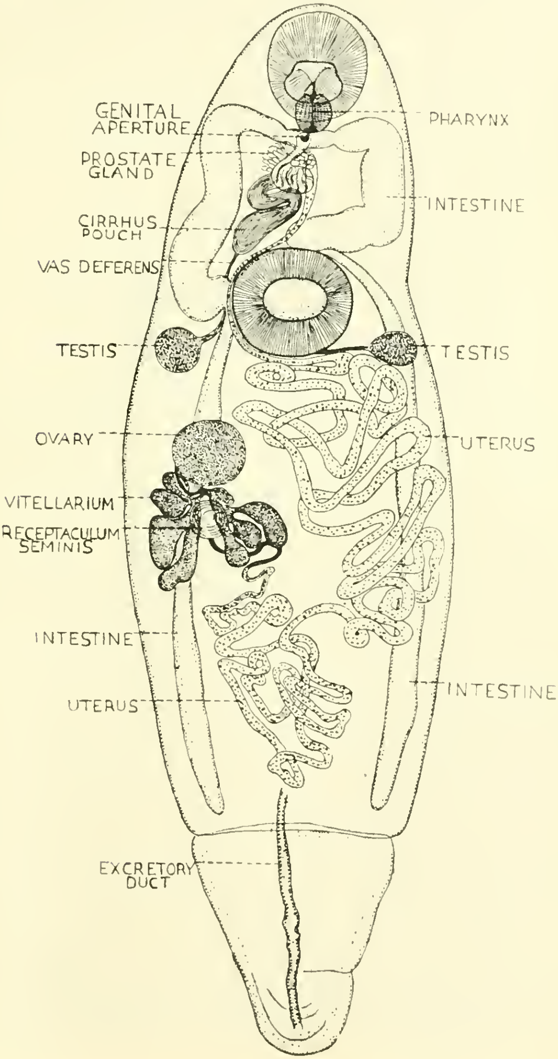


FIG. 13. *Distomum ocreatum*. × 18 dia.

In the caecal part of the stomach of a conger eel about five feet long over 100 specimens of this distomid were found. The worms while alive were blood-red in colour. The size was variable: when dead after killing in fresh water they were from 5 mm. to about 2·5 mm. in length. The anterior extremity in this state is usually bent ventrally towards the ventral sucker. The following measurements relate to a specimen which had been killed in an expanded condition by slight pressure between two glass slides.

Total length: 8 mm.
Greatest breadth: 2·25 mm.
Diameter of oral sucker: 0·88 mm.
Diameter of ventral sucker: 0·92 mm.
Diameters of ova: 0·024 × 0·013 mm.

The species is, doubtless, near *Distomum ocreatum* of Molin, but the characters of the appendiculate Distomids with suckers of nearly equal size do not appear to be very well marked, so I add the following description.

The suckers are very nearly equal in size, the ventral being usually only very slightly the larger of the two. The mouth is sub-terminal and lying very near to the pharynx. There is no distinct oesophagus and the intestine passes transversely across the body without any distinct fork. In life the rhythmical movement of this transverse portion of the intestine is very well marked. Successive peristaltic movements pass outwards from the junction of intestine and pharynx, towards the lateral curves of the former with great regularity, and the food contents are throughout the first half of the length of each intestinal ramus in a state of constant agitation. The intestinal rami do not descend into the appendix—at least not in the specimen figured: in other specimens, however, the opposite appeared to be the case. The

appendix is, at the greatest, about one-third of the entire length of the animal. It is very retractile and easily ruptured by undue pressure.

The characteristic serrations on the margins of the body, due to plications of the skin, were not clearly seen.

The main excretory channels are two ducts which curve round from the anterior part of the body and meet behind the ventral sucker, then pass down the mid line of the body to the termination of the appendix as a single channel.

The ovary is situated about half-way between the extremities, ventrally and a little to one side, and is nearly spherical in shape. Immediately posterior to it are the vitellaria. There are two principal lobulated masses. In the specimen figured there are three lobes on one side and four on the other. At the anterior extremities the two vitelline masses are connected together by a short bridge of tissue and from this a short duct connects with the ovary. The shape of the vitellaria is far from being constant, and little value can be placed on the extent to which each lateral mass is lobulated. In some specimens the sub-division was very much less than in the figure.

Over the middle part of the vitellaria was a rounded structure which is apparently the receptaculum seminis. Neither in preparations of the entire worm nor in section, however, could the exact relations of this structure with the vitellaria and oviduct be made out.

The uterus in some specimens is very voluminous. In no case did it descend into the appendix. It is aggregated on the side of the body opposite to the ovary and vitellaria. The ova are very uniform in shape, and the diameters (0·025 × 0·013 mm.) agree very well with

the figures given by Linton for the distomid identified by him as Molin's *D. ocreatum.*

The testes are small, rounded bodies situated one on each side of the ventral sucker, and fairly remote from the ovary. The vasa efferentia curve round to one side of the ventral sucker, and enter the bursa of the cirrus, which lies entirely in front of the sucker, but almost in contact with the latter. The uterus opens externally very near to the male genital aperture, and apparently into a common genital cloaca. Round the extremity of the bursa and the cirrus is a prostate gland, which, however, is not a very prominent structure. The armature of the cirrus itself could not satisfactorily be made out.

The above characters are mostly those of *Distomum ocreatum,* Molin, and I think these specimens may safely be referred to this species.

Distomum appendiculatum, Rudolphi.

From stomach of whiting (*Gadus merlangus*), Shoals, March, 1906.

One specimen of an appendiculate distome was found in the stomach of a whiting, along with some other specimens of a distomid not yet identified. The species is probably *D. appendiculatum,* but the diagnostic characters of the distomids with a retractile appendix are rather confused, and it may be worth while to give a description of the present form. The measurements are:—

Length: 5 mm.
Width: 1 mm.
Diameter of oral sucker: 0·17 mm.
Diameter of ventral sucker: 0·4 mm.
Ova: 0·02 × 0·01 mm.

Fig. 14 represents the animal with the appendix

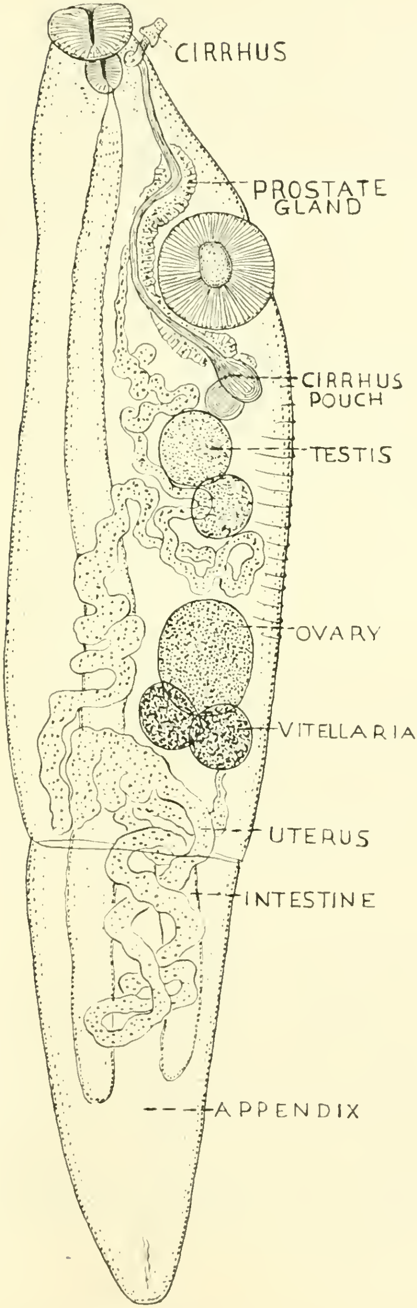


FIG. 14. *Distomum appendiculatum.* × 34 dia.

fully expanded. The skin is almost everywhere smooth, and only in one place shows the characteristic plications. The ventral sucker is rather more than twice the diameter of the oral one, and is situated well forward. There is a short pharynx followed by a very short oesophagus. The forks of the intestine are straight and cylindrical, and extend well down into the appendix. The ovary is situated about halfway between the extremities and is oval in shape. Immediately behind it are the vitellaria, which are two in number, small and nearly globular in shape, and in close contact with the ovary. The testes lie midway between ovary and ventral sucker. They are almost globular in shape and lie obliquely across the body. Almost in contact with the anterior margin of the testis are the seminal vesicle and cirrus pouch. The cirrus itself is long, and is surrounded for the greater part of its length with a compact prostate gland. It opens on the posterior margin of the oral sucker. Apparently the female genital aperture is very near to the male opening, but it was not visible in the preparation. The uterus is long and greatly convoluted in the region of the ovary and vitellaria. Like the intestine, it extends well down into the appendix. The worm when alive was translucent, but possessed no distinct colour.

Distomum vitellosum, Linton.*

From Flounders (*Pleuronectes flesus*), Piel tanks.

In June, 1906, Mr. A. Scott dissected several mature flounders which had been kept in the tanks at Piel Hatchery during the whole of the previous winter, and found a great number of mature distomids in the

* Linton: Bull. U. S. Fish. Comm., Vol. 10., 1899, p. 290, pl. 37, fig. 38.

intestines of several specimens. The characters of these worms agree closely with those of *D. vitellosum*, a species

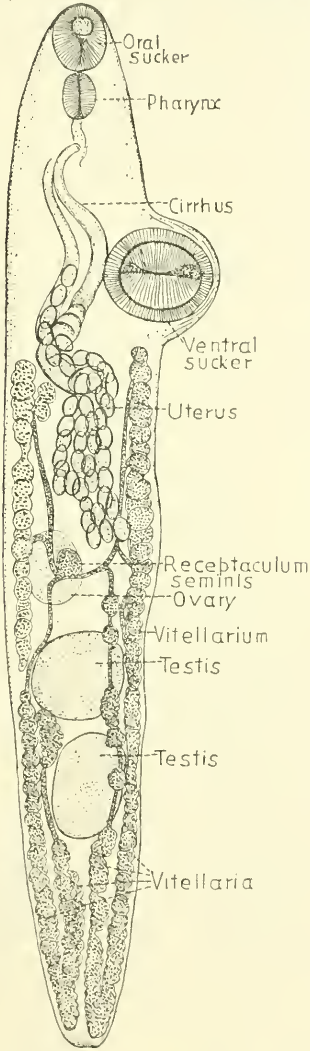


FIG. 15. *Distomum vitellosum.* × 70 dia.

described by Linton from the American hake (*Merluccius*

bilinearis), and I think it probable that the distome described here is the above species.

Measurements made from a specimen killed in fresh water and preserved in formalin are:—

Length: 2 to 2·5 mm.
Breadth: 0·25 to 0·5 mm.
Diameter of oral sucker: 0·23 mm.
Diameter of ventral sucker: 0·42 mm.
Diameters of ova: 0·08 × 0·04 mm.

Fig. 15 represents one of these worms seen rather from the side, but slightly twisted. The skin is smooth and without armature; the body sub-cylindrical, and in death with a very noticeable bend towards the anterior extremity. The ventral sucker is very prominent, and is situated on a kind of protuberance. It is nearly twice the diameter of the oral sucker. The pharynx is large, and there is a short oesophagus—the intestinal forks run straight back to near the posterior extremity. The ovary is situated about halfway between the extremities, is globular in shape and rather small. Immediately in front of it is the uterus, which in most specimens formed a compact mass consisting of, apparently, few convolutions and containing a comparatively small number of eggs. The vitellaria are very conspicuous structures, and in many specimens filled the body, almost preventing a proper view of the other genital organs. There are usually four bands of rounded, irregularly-shaped gland; in the figure these bands are seen from the edges, but when the worm is rotated through 90° they appear to be much more voluminous, the bands then being seen from the flat sides. In many specimens the vitelline ducts are very conspicuous, they run through the middle of the band-like masses of vitellaria, and join to form a transverse duct which runs across the body. The ovary is

situated on the course of this transverse duct, and near to it is a small rounded body, which is probably the receptaculum seminis. The ovary itself is a globular structure. The testes are two in number, and are situated at about the posterior third of the body. The cirrus pouch and seminal vesicle lie behind the ventral sucker, and the cirrus runs forward to open near the posterior margin of the pharynx, about halfway between the ventral and the oral suckers. The female genital aperture is situated close to that of the male organs.

Distomum mollissimum, Levinsen.*

From intestine of *Belone vulgaris*, Foulney Island, 1906.

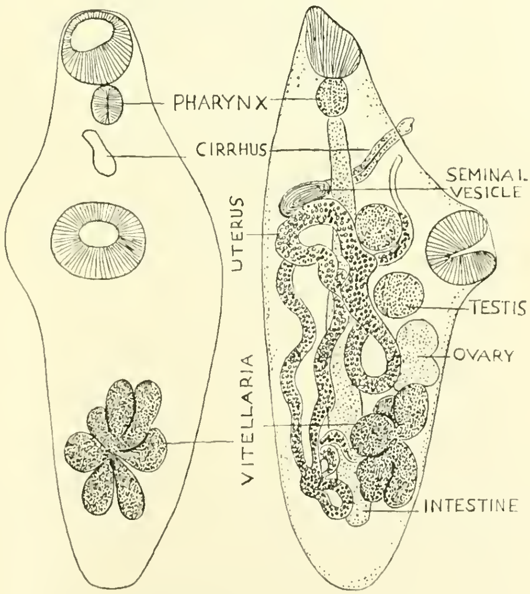


FIG. 16. *Distomum mollisimum.* × 50 dia.

*Oversigt d. k. Danske vidensk. Selskab Forh. No. 1, Tab. 1, 4. Kjobenhavn, 1881.

Several small distomids were sent me by Mr. A Scott, who found them when dissecting a garfish—they certainly belong to the above species. The worm is easily recognised by the star-shaped vitelline glands. It is about 1·5 mm. in length, almost colourless and extremely fragile. Even the pressure of the cover glass is sometimes enough to rupture the preserved specimen. The figure (fig. 16) is constructed from a specimen preserved in formalin. Levinsen found his specimens in the intestine of *Cottus scorpio*. Hitherto all *Cotti* dissected from the Irish Sea have failed to provide this distome.

Distomum, sp.

From *Labrus mixtus*, Morecambe Bay, 1906.

Three small distomids from the intestine of a wrasse do not appear to answer to any published descriptions I have seen. The specimens were, however, only seen after preservation in formalin, and it frequently happens that the details of structure necessary for certain diagnosis can only be made out in living distomids. Fig. 17 represents all that can be seen by staining the specimens to which I refer. The measurements of the worm are:—

Length: 1·2 mm.
Breadth: 0·5 mm.
Diameter of oral sucker: 0·11 mm.
Diameter of ventral sucker: 0·24 mm.
Diameters of ova: $70\mu \times 50\mu$.

The ventral sucker is thus about twice the diameter of the oral one. No details of the oesophagus or intestine could be made out. The vitellaria are represented by a comparatively small number of rather large, irregularly-shaped glands distributed throughout the body. No trace of ovary could be made out with certainty, so it is not represented in the figure. The testes are two large oval

bodies, placed well back near the posterior extremity. Neither the ducts of these bodies nor those of the vitellaria were seen. The cirrus is long, and apparently unarmed. The cirrus pouch and seminal vesicle appear to lie entirely in front of the ventral sucker, but it was difficult to be sure of this. A characteristic feature of the

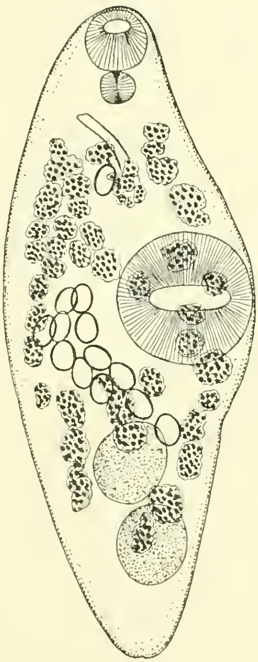


FIG. 17. *Distomum*, sp. × 70 dia.

anatomy of this distomid is the small number of ova. In the three specimens, 12, 13 and about 24 were the numbers of eggs counted. These are comparatively large, are thin shelled and possess no appendages.

In the characters of the vitellaria, the position of the testes and cirrhus and the large size and limited

number of the ova, the specimens agree with *Distomum oculatum* of Levinsen.* But the so-called eye spots of the latter species are not represented in my specimens, and the size of the ventral sucker and the presence of a distinct armature in Levinsen's species render it unlikely that the specimens here described are *D. oculatum*. Several specimens from *Bairdiella chrysura* described by Linton† shew a greater resemblance, but these distomids, too, do not appear to have been identified with any known species.

Derogenes varicus, (O. F. Müller).

From pyloric part of stomach of Whiting (*Gadus merlangus*) "shoals," off Cumberland coast, April, 1906.

About half-a-dozen small trematodes were obtained from the above host. The worms were dull red in colour when alive. The figure (fig. 18) is constructed from observations made on the living worm.

The principal dimensions are:—

Total length: 2 to 2·5 mm.;
Greatest breadth: 0·56 mm.;
Diameter of oral sucker: 0·2 to 0·27 mm.;
Diameter of ventral sucker: 0·4 to 0·43 mm.;
Diameters of ova: 0·055 × 0·03 mm.

The body is cylindrical, or very slightly flattened. The greatest breadth is in the region of the ventral sucker, where it is about one-fourth of the total length. From this region the body tapers in both directions and the posterior end is usually slightly more pointed than anteriorly. The skin is quite smooth and possesses no spines.

The ventral sucker is rather variable in diameter,

* Loc. cit.

† Bull. Bureau of Fisheries, Washington, vol. 24, 1904, pl. 23, figs. 168, 169.

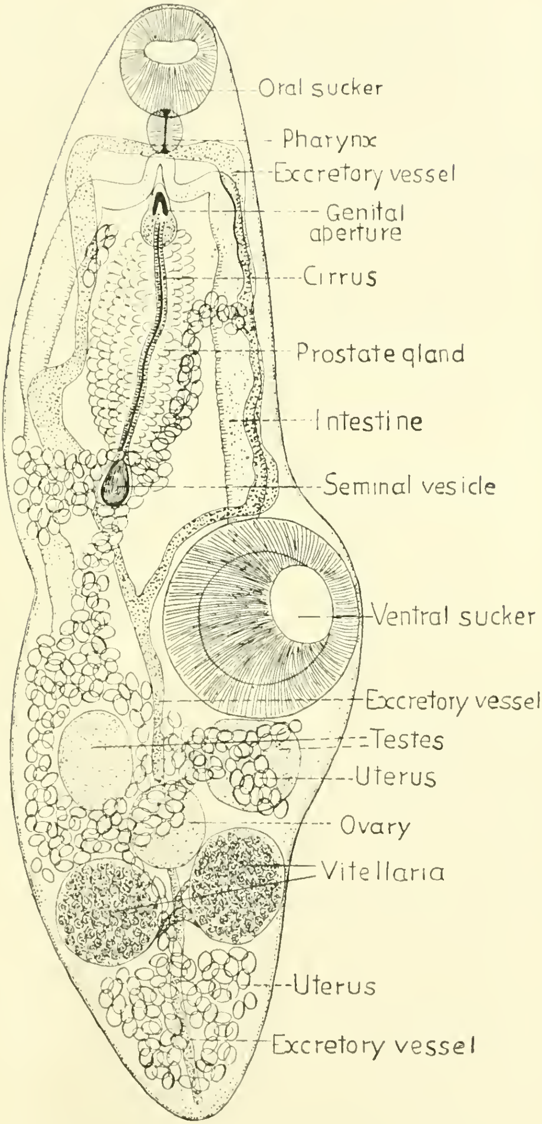


FIG. 18. *Derogenes varicus.* × 75 dia.

but is generally very nearly twice the size of the oral sucker. It is situated rather behind the middle of the body, and in the dead worm, usually on an elevated part of the latter. The openings of both suckers are very nearly circular in outline.

The pharynx is small and oval in shape. There is no distinct oesophagus and no real undivided section of the intestine. From the pharynx the intestinal rami pass transversely to the margins of the body, and then run back as wide voluminous vessels to near the posterior extremity. In the worms, after killing in fresh water, and subsequent preservation in formalin, the walls of the intestine, when seen in optical section, have crenulated outlines.

In the living worms the excretory system is very obvious, but disappears entirely after preservation, and is only indistinctly seen on staining with carmine. The main vessel runs transversely across the body just behind the pharynx, then backwards as two very prominent, rather wide vessels forming a loop. These unite at about the mid transverse line of the ventral sucker, and then pass back in the median line of the body to the posterior extremity. The excretory pore is situated terminally. Often at the summit of a small papilla.

The vitellaria lie far back, about halfway between the posterior margin of the ventral sucker and the posterior extremity of the body. They are rather large bodies, quite regular in outline, spherical, or slightly flattened dorso-ventrally, sometimes oval and elongated in the longitudinal axis of the body. They are made up of a great number of small glandules, but the whole structure is enclosed in a distinct capsule, a short transverse duct unites them and from this the vitelline duct passes forwards to the ovary. The latter is a rounded

structure lying between, and anterior to the vitellaria, and smaller than either of the latter glands. In none of the specimens could I make out with certainty the position and relations of a receptaculum seminis.

The testes are two in number. They are rather small, and not at all conspicuous in either living or preserved specimens. The vasa deferentia cannot easily be traced; probably they are separate and unite quite close to the seminal vesicle, or possibly enter the latter independently. The cirrus and its accessory structures lie all in front of the ventral sucker. The seminal vesicle is small and oval in shape. From it the ductus ejaculatorius passes straight forwards in the median line as an apparently strongly muscular organ, terminating in a prominent genital papilla which is situated immediately behind the forking of the intestine. Throughout all its length, between the seminal vesicle and the genital papilla, the ductus ejaculatorius is surrounded by a very voluminous prostate gland.

In none of my specimens could the exact configurations of the convolutions of the uterus be made out with certainty. It is voluminous in most specimens and is crowded with ova. These latter are thick-shelled and slightly yellow or red in colour. The vagina and cirrus both open into a common genital cloaca, situated at the summit of the genital papilla. The opening of this genital cloaca is in all my specimens Λ-shaped, or crescentic, the apex of the V, or the convexity of the crescent being directed forwards.

Most of these characters would apply equally well to *Derogenes minor*, Looss,* or to *D. varicus* (O. F. Müller).† It is indeed rather difficult to make out absolutely diagnostic differences between these two species. *D. minor* was described by Looss from a

Labroid fish (*Labrus merula*) taken in the Bay of Trieste, and *D. varicus* has various hosts, the latest description being that of Odhner, who found the Trematode in a dab (*Pleuronectes limanda*) from the West Coast of Sweden. Odhner's specimens resemble those described here in that the vitellaria are rounded and regular in outline instead of being slightly mulberry-shaped as in Looss's species. This is the only significant difference apparent between the two species.

III.—PROTOZOA.

Ichthyophthirius multifiliis, Fouquet.

Trichodina, sp.

In June, 1906, Inspector Halsall of the Southport Sanitary Department sent some roach which had been living in Hesketh Lake, Southport. Some little time previously an epidemic had broken out among the fishes in this pond. Only the roach were affected, and pike, perch and eels living in the same water showed no signs of disease. The epidemic produced considerable mortality among the roach for about a month, but by the end of July it had run its course, and there were then thousands of young fishes in the lake, all of which appeared to be quite healthy. The fish, when received at the laboratory showed no apparent outward signs of illness. The skin was bright and clean and without traces of fungus. Dissection showed no internal lesions, and smears made from the blood and various organs

* Looss: b. Einige Distomen der Labriden des Triesten Hafens, Centralbl. f. Bakteriologie, Bd. 29, Abth. 1, p. 437, 1901.

† Odhner: Die Trematoden des Arktischen Gebietes; Inaugural Dissertation Univ. Upsala; Jena, 1905.

shewed that parasites such as myxosporidia were absent. The gills were then examined, and these were found to be pale and not in a very healthy condition; also small, rounded white specks could just be seen with the naked eye, and when these were examined in detail they were seen to be ciliated infusorians. Fig. 4, pl. VIII, represents one of these organisms. They varied greatly in size, the largest being about 0·75 mm. in length and 0·47 in breadth, and the smallest about 0·3 × 0·28 mm. Usually they were oval in shape, but some were quite round. Their numbers were not considerable; in a small piece of gill, from one of the smaller fishes, which was stained and mounted whole there were 17 parasites. There were 30 double filaments in this piece of gill. In some other pieces of gill roughly examined the parasites appeared, however, to be more abundant than is stated above. They lie in the gill between the filaments and compressed by the latter. They were also found on the internal walls of the operculum and branchial cavity. The parasite is completely covered by fine cilia. The nucleus is situated towards one end, or near the middle of the body, and is large and horse-shoe shaped. It is very coarsely granular. The mouth is situated at the opposite end and is small and very definite in outline. A faint, longitudinal striation may be observed in the body. Round the margin, or rather underneath the cilia, is an evident cortical layer. Small vacuoles are very numerous in some specimens.

All these characters are those of *Ichthyophthirius multifiliis*, Fouquet, and I have no hesitation in thus identifying the creature. It is a skin parasite, which has been described as infesting 28 or 30 species of fresh-water fishes in the rivers and lakes of Germany, France, Holland and the United States of North

America.* So far as I know, it has not previously been observed in British waters. The parasite is always described as inhabiting the skin of the infested fish, where it excavates little cavities or galleries or forms pustules. These cavities or pustules may contain one or a number of individual parasites. A characteristic spotted appearance is thus conferred on the skin of the fish. *Ichthyophthirius* reproduces either by fission (Stiles), or by the method of encystment. Eventually the parasite leaves the host, and after swimming about in the water for some time surrounds itself by a cyst wall, when it falls to the bottom. The young ciliated individuals leaving the cyst then pass through a free-swimming stage and reinfect fresh hosts. It is by attacking these free-swimming forms that the epidemic in a tank or small pond can most easily be fought. It appears to be impossible to destroy the parasites while living in the skin of the hosts, but if the fishes be taken from the aquarium and common salt added to the latter with a copious supply of fresh water the free-swimming individuals are easily killed. This treatment, practicable though it may be on a small scale, is, however, difficult in the case of a very large pond or "lake."

It is difficult to say what the specific pathogenic action of the parasite may be. In the roach from Hesketh Lake there was no general infection of the skin—indeed I could not detect the parasite there in any of the specimens examined. Even in the gills the numbers were few, and it seemed difficult to believe that the mechanical destruction of the tissues of the filaments was enough to account for the death of the fish. It was, however,

* There is an account of the parasite, with a summary of the literature by C. W. Stiles in Bull. U.S. Fish. Comm., vol. 13, 1893, pp. 173-190. See also Hofer Handbuch der Fischkrankheiten, p. 122; Munchen, 1904.

impossible to avoid associating the presence of the infusorian with the death of the fish, as no other cause was apparent which would account for the large mortality experienced. It is just possible that the infusorian kills the fish by forming a toxine which is absorbed through the delicate epithelium of the gills, or at the abraded surface of parts of the latter structures.

Associated with the *Ichthyophthirii* in some of the fishes were infusorians belonging apparently to the genus *Trichodina.* This is the well-known ciliate found on the common *Hydra.* The number of specimens found were, however, few, and in such bad condition that the certain determination of the species was not possible.

Lymphocystis johnstonei, Woodcock.

A small sole was sent to the Laboratory in April last by Dr. Masterman, H.M. Inspector at the Board of Agriculture and Fisheries. The fish was captured off the East coast of England by a steam trawler, and sent to the officials of the Board in a sample box of various fishes. The fish is an immature female about 7½ inches in total length, and was apparently healthy and in good condition. But the greater part of the surface of the skin was covered over by very small, white, and spherical opaque bodies which were evidently parasites of some kind. They were densely scattered over the ocular side of the fish particularly on the dorsal and ventral regions of the body. On either side of the lateral line the skin was very nearly free from them, but, towards the dorsal and anal fins they became more densely aggregated together. On the fins they were most abundant, particularly on the dorsal fin near the head and on the tip of the pectoral fin. Here they formed dense clusters seated on most of the fin-rays. The skin of the head was

densely covered with these structures; the tail also contained a few; the blind side of the fish also showed a certain number, but far less than on the ocular surface—probably on account of the attrition caused by the fish creeping over the surface of the sand. The little bodies in question were quite colourless, but very opaque, and easily discernible by the naked eye. They were nearly spherical in shape; flattened perhaps in one direction, and where they were closely packed together—as in the clusters on the fins—their shapes were polygonal. Their average diameter was about 0·32 mm.

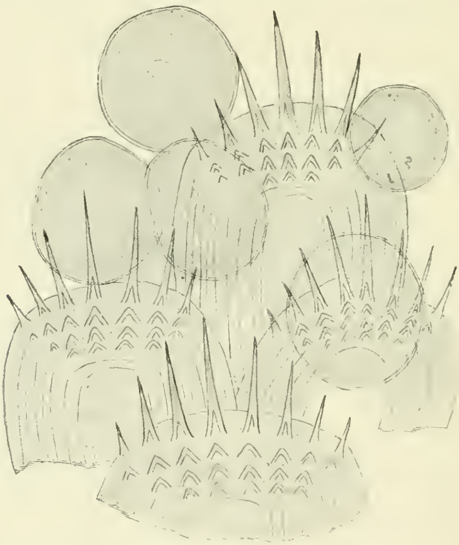


Fig. 19. Skin of Sole infested with *Lymphocystis johnstonei*. × 60 dia.

The fish had been preserved in formalin and the skin and the structures on and in connection with it were well preserved, but the body cavity had not been opened and the viscera were not in good condition for close examination. But, apparently, the peritoneum and mesenteries

were quite free from the parasites occurring on the skin. The gills were also free and apparently quite healthy.

Fig. 19 represents a general view of a part of the skin which has been stained with carmine and cleared in clove oil. The parasitic structures are mostly covered by the scales. Each is covered over by a thin fold of epidermis. Usually they are situated beneath the posterior margin of the scales under the fold of epidermis which is reflected over the latter. Sometimes they are apparently quite free from the surface of the skin and can easily be detached by the point of a scalpel, but in such cases they are attached by a delicate pedicel of epidermic tissue. In sections of the skin taken in a transverse plane they can be seen lying beneath the tips of the spines of the scales, which are then cut transversely.

In section each of the parasitic bodies is almost certainly a unicellular structure. It is surrounded by a fairly thick, apparently structureless capsule, which stains with difficulty and is, therefore, more easily seen in the unstained preparations. Within is the cell body, containing near the centre an irregularly-shaped included portion surrounded by a differentiated portion of the matrix, which may represent a nuclear membrane. Within this is what may be called a nucleus. There is a matrix of finely granular substance in which are usually two or more rounded karyosomes.

The cell substance outside the nucleus stains rather more darkly than that within because of the presence of numerous granules. It shows no clearly marked cortical zone, but round the periphery are a number of reticular structures, very irregular in shape and size, and usually surrounding a portion of cell substance which stains more lightly than that in which the reticula are imbedded. Each of these reticula appears to consist of innumerable

closely apposed granules, which take chromatic stains very easily. Close underneath the capsule, again, are a number of smaller, more closely aggregated collections of similar granules, usually spherical, or nearly so, in shape, and staining less deeply than the reticula just described.

Most of the structures above described are to be seen in the remarkable sporozoan, *Lymphocystis johnstonei*, described by Woodcock,* and it is difficult not to identify the two parasitic structures as the same organism. The mode of occurrence of the structures—on the skin and fins—is the same, and despite the difference in size I regard it as probable that in the case just described we have to deal with an invasion of *Lymphocystis* individuals, and that the nature of the host and, particularly perhaps, the nature of the skin of the sole—where we find strongly ctenoid scales, instead of the comparatively soft cycloid structures found in the flounder—is the reason of the difference in size. The difference in diameter, 0·32 mm. and 1 to 1·5 mm. in the sole and flounder respectively, may easily be explained by such considerations, and one may, indeed, find many examples of analogous differences in size in identical parasitic species living on somewhat different hosts.

IV.—DERMAL CATARRH IN SALMON AND DAB.

Two cases of pathological changes in the skin of fishes have been observed which do not appear to be referable to parasitic invasions of any kind. In September, 1904, Mr. R. Okell sent me some salmon parr caught in a stream near Douglas which appeared to be suffering from some obscure skin disease, obviously not due to *Saprolegnia*. Fish thus infected were quite

* In An. Rept. Lancashire Sea Fish. Laby. for 1903, pp. 63-72. pl. III.

abundant at this time, but about the middle of October the epidemic had greatly subsided, though even then about 10 per cent. of the salmon parr observed seem to be infected. The extent of skin affected in the case of specimens caught at this time also appeared to be less than formerly was the case. All this time salmon parr alone were infected. Brook trout do not appear to have suffered.

Fig. 5 (pl. VIII) represents the tail portion of one of these fish with a characteristic skin lesion. In all cases the naked eye appearance was pretty much the same as that figured, though not always so prominent. In the less strongly infected fishes the skin appears to be covered in places with a thin, whitish scum, like felted or compressed cotton wool. This can easily be rubbed away and then the skin underneath appears to be quite normal, the scales retaining their usual appearance. Here and there this growth is, however, much more prominent. For instance, in the case figured there was a raised whitish tumour on each side of the body just above the anal fin. This growth was raised about 2 mm. above the surface of the skin. It had usually a slightly crenulated margin and had surface markings indicating roughly the position of the scales underneath. In the case of some of these larger growths, however, the skin underneath the adventitious tissue was disorganised and the scales came away easily.

Microscopic examination showed no traces of a mycelium so the presence of a fungus was out of the question. Neither were there any traces of Myxosporidia. These were specially looked for as the naked eye appearance of some of the fish was not unlike the condition of "Beulenkrankheit" (Myxoboliasis). Smears were made from the blood and from all the visceral organs,

and portions of muscle tissue were examined, but no trace of myxosporidia could be detected. The gills, too, were quite normal. The skin growth was examined further for the presence of Infusoria, such as *Costia*. *Costia necatrix* produces appearances on the skin of various fishes not unlike that observed in this case. In fact, it was possible to eliminate the possibility that sporozoan or infusorian parasites were responsible for the condition. The possibility that bacteria were concerned was also considered, but a search for these was unsuccessful, and I had no opportunity of examining fresh material.

Sections of the skin, including portions of the growth were then made and stained with methyl-blue-eosin, and Heidenhain's iron haematoxylin.

Part of such a section is represented in fig. 1, pl. VIII. It will be seen that the skin is very much altered. The scales are in some cases quite displaced, and may even be seen buried up in the tissue of the tumour. The dermis is always quite unaffected; whatever the disease is it affects only the epidermis. This latter layer is quite changed. In a normal fish it consists of roughly polyhedral cells lying close together, and contains large mucus cells included among the others. At the base is a very regular layer of cubical cells, and at the free surface of the skin the epidermal cells become flat and horny. The tissue of the tumour replaces the epidermis, which, as a normal structure, has entirely disappeared. Instead of it we see a densely compacted mass of smaller cells. These are arranged in aggregates somewhat resembling tubercles. In the axis of each tubercle is a core of fibrous tissue, with a structure very difficult to determine; and here and there cavities containing groups of small bodies, not unlike, in size and shape, masses of

myxosporidian spores. A small portion of the tumour as seen with a high power immersion lens is depicted in fig. 2, pl. VIII. Part of the core of one of the tubercles is shown with a number of the small oval bodies referred to. These have an average length of about 5μ. They stain densely with eosin or iron haematoxylin, and show no obvious structure. They are not at all numerous.

The rest of the tissue consists of cells of various sizes, with apparently some structureless material serving as a matrix. There are two kinds of these cells. One kind stain densely, are rather smaller than the others, and show a definite nucleus The other kind appear also to be nucleated, though it is difficult to be certain, and are larger. Indeed one can easily say too much regarding the cytology of this tissue, for the preservative was only formalin and I had no opportunity of fixing the thing properly.

I think the only probable explanation of this condition is that it represents a catarrh of the skin, such a condition as is described by Hofer* as "Erkaltungskrankheiten." I have not seen any such condition as is represented by Hofer's plates VIII and IX, but the general "turbidity" of the skin, the delicate waxy bloom which he speaks of, is well shown in some of these specimens. It appears to be a paradox, Hofer says, to speak of a fish as catching cold or catarrh; still that such an ailment should be experienced by a fish is not so surprising as it at first appears to be. In a cold blooded animal the heat regulating mechanism, which is so characteristic and important a feature in the physiological economy of a warm blooded creature, is conspicuously absent. The temperature of a fish is always that of the medium in which it lives, or only a very little higher.

* Handbuch der Fischkrankheiten, Munchen, 1904, p. 87.

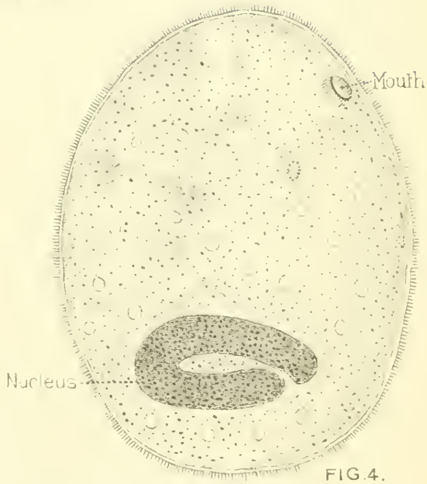
Such sudden changes of temperature as a warm blooded animal must accustom itself to are as a rule not experienced by fishes, for changes in the temperature of even a small mass of water such as a pond take place much less rapidly than corresponding changes in the atmosphere. Nevertheless, there are circumstances in which the water temperature may change fairly rapidly —such as, for instance, would be produced by the quick migration of a fish from one part of a small stream into another, or into a pond; or, perhaps, by a sudden freshet in a small stream produced by cold rain or melting snow. Still more would such change be experienced by fishes living in captivity as for instance in fish-breeding establishments; and it is chiefly in relation to fishes living in these conditions that catarrh of the skin has been observed and studied.

These Manx salmon parr were then probably suffering from some kind of dermal catarrh. Indeed I can suggest no other explanation of the lesions observed.

The other apparent cases of dermal catarrh observed were in several dabs (*Pleuronectes limanda*) which have been taken during the last year or two. One fish brought to the Piel fishermen's classes in April, 1906, by Capt. Wignall showed the condition very well. The fish was a mature male with ripe testes and apparently in normal condition. But on either side near the tail was a soft, white, slightly translucent tumour not unlike those described from the Manx salmon parr. The tumour had a papillated surface, was about 1 cm. in diameter, and about 2 mm. in height. In the fresh condition there was an irregular radiate arrangement of blood capillaries infiltrating its mass. Smears from a part of this growth were made and stained by Romanowsky's method, and also by Heidenhain's iron haematoxylin. The blood of

FIG. 1.

FIG 3.



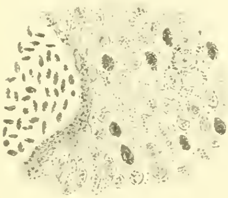


FIG. 2.

FIG. 4.

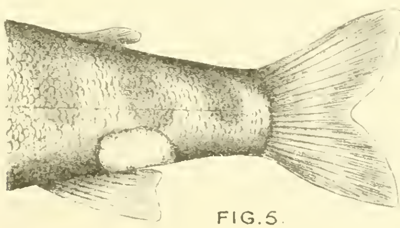


FIG. 5.

1 – 3. Tumour on skin of Salmon Parr.

4. Ichthyophthirius multifiliis Fouquet.

5. Tail of Salmon Parr with tumour.

J Johnstone. del.

the fish was also examined, but was quite normal. Indeed, with the exception of the tumour described no other evidence of disease could be discovered.

The tissue of the tumour showed a general resemblance to that described in the case of the young salmon. But there was a much larger quantity of broken down material, of a finely granular nature, lying between the cells. The latter are apparently epidermal cells altered considerably, staining only very lightly with Romanowsky, but deeply with iron-alum haematoxylin. Among these cells are nests of bacteria staining well with Romanowsky. Several of these are represented in fig. 3, pl. VIII, and it will be seen that they are of very various forms. The long delicate bacillus occurs rather rarely; it is about 10μ in length. Other forms are short curved rods and thick, dumpy bacilli, most of which stain as if spore formation were in progress, but are probably only the involution forms of a bacillus akin to the long slender forms. These bacilli are not very numerous, though a fair number could be seen in every field. An attempt was made from the fresh tissue to set up a cultivation on nutrient gelatine at ordinary room temperature, but no results were obtained. Probably they represent only a secondary infection on a partially broken down proliferation of the epidermis. The whole appearance of the latter is so similar to that in the Manx salmon parr that I am inclined to regard this also as a case of dermal catarrh. A mechanical injury is out of the question as the skin underneath was almost normal and no traces of infection by a sporozoan or other parasite could be detected.

ON A MYXOSPORIDIAN INFECTION OF *GADUS ESMARKII.*

By Jas. Johnstone.

WITH A NOTE ON THE IDENTIFICATION OF THE PARASITE.

By H. M. Woodcock, D.Sc., Lister Institute of Preventive Medicine.

I.

In 1889 Günther* first recorded the presence of the Norway Pout, *Gadus esmarkii*, in British waters. This fish, previously known only in Scandinavian waters, was noted by Gunther in the Firth of Clyde, and in some of the Western Scottish Lochs, at depths varying from 26 to 80 fathoms. Speaking of the characters of the fish Günther says, " Many of them suffered from a singular affection of the eye, namely the whole eyeball, and also a greater or lesser part of the iris, being covered with cysts containing a cheesy matter."

Again in 1900 Fulton† makes a similar observation. *Gadus esmarkii*, belonging to the so-called Scottish and Scandinavian types, was found by him in the Northern part of the North Sea, where it appears to be fairly abundant, and in the Firth of Clyde. Fulton says that " a very large proportion of those taken in the Firth of Clyde had one or both eyeballs affected in the manner described by the author named [Günther], (the cysts, however, containing fine granules) but no specimen from the North Sea was observed to be so affected."

In March of 1906, a Norway Pout was caught in a

* Proc. Roy. Soc. Edinburgh, vol. 15, 1889, p. 212.

† Rept. Scottish Fishery Board, 19, pt. 3, 1900, pp. 282-4.

shrimp-trawl worked in shallow water near Morecambe, and sent to me. This specimen had both eyes affected in the manner described by Günther and Fulton.

These are the only instances of this affection of the eye which, so far as I am aware, have been observed. Although the fish has been known for a long time on the coasts of Scandinavia, and has since been found on most of the coasts of the British Isles, the eye parasites have only been found on the West Coast of Britain. Probably the specimen found at Morecambe is one of many which have migrated into the Irish sea through the North Channel.

Fig. 1, pl. IX represents the head of the specimen (twice natural size). The eye is perhaps larger than in normal specimens. Round the peripheral part of the cornea, and covered loosely by conjunctiva are a number of milk-white rounded or oval bodies, from about 1 to 3 mm. in diameter. Several of these have fused to form elongated masses, which take the curvature of the periphery of the eye. Growing out from the lower margins of this ring is a botryoidal mass of similar material which encroaches on the pupil. When one of the eyes was removed it was seen that these adventitious structures had invaded the lateral and posterior parts of the bulbus oculi.

These structures remind one of pustules. When pricked (in the fresh condition) a thick, white, pus-like substance could be squeezed out. But when a trace of this was examined under even a low power of the microscope it was immediately seen that the structure was a Myxosporidian cyst. The "fine granules" filling up the interior were spores containing two polar capsules, and in some cases, two polar filaments were seen under a high power.

Fig. 3, pl. IX represents a nearly meridional section of the wall of the bulbus oculi. Apart from the shape of the bulbus, and the presence of the processus falciformis and campanula, the fish eye does not differ greatly from that of higher Vertebrates. In the wall, however, we find a choroid layer possessing features solely piscine, and also the peculiar argenteal layer. The sclerotic consists of two layers, (1) a layer of cartilage, ceasing some distance behind the iris: on the internal surface of this is the argentea; and (2) a fibrous layer which lies external to the cartilaginous layer. This feature is, of course, paralleled among other Vertebrata.

The intrusive cysts lie within the thickness of the cartilaginous layer of the sclerotic. This latter is, of course, quite thin in the normal eye, whereas in the diseased specimen the cysts are sometimes over 2 mm. in diameter. The multiplication of the Myxosporidian within the cartilaginous sclerotic has, therefore, distended the latter layer. In section a layer of cartilage, sometimes, however, very thin, can be traced all round the cyst. In other parts of the section the cartilage thins out and almost disappears, being either mechanically stretched or, perhaps, reduced by the reaction of the Myxosporidian tissues. The other parts of the eye were apparently quite normal. The function of the organ had not apparently been affected; though it is probable that a kind of cataract might easily be induced by the invasion of the cornea by the cyst masses. This process has indeed begun in the eye figured. J. J.

II.

Mr. Johnstone kindly sent me a couple of smears made from the contents of one of the cysts above described, expressing his opinion that a Myxosporidian parasite was concerned; and asking me to identify it. On examining the smears, I saw that they consisted entirely of spores, evidently belonging to a Phaenocystan parasite, for two brightly refringent polar capsules were visible in each. One of the slides was stained with Heidenhain's iron-haematoxylin, the other with thionin. For some reason or other the first method did not prove a success, the stain persisting in the spore-wall in a rather blotchy manner, and obscuring the contents; while the polar capsules did not retain it at all. By the second method the spore-wall itself remained unstained, the polar capsules were deeply stained, and the various nuclei, though not retaining the stain as much as was desirable, could often be made out with a little trouble.

Two spores are seen in fig. 2. In shape they are slightly ovoid, their dimensions averaging 10 μ in length by 8 μ in breadth. The two polar capsules (*p.c.*) are situated near one end of the longer axis; the length of each varies from $3\frac{1}{4}$ to $3\frac{1}{2}$ μ. Unfortunately, I could not find a single spore in which either or both of the polar capsules had the filament evaginated. This was a little surprising, as in a similarly prepared slide of another parasite (*Sphaerospora platessae*) which I have previously characterised,* the stimulus of spreading the smear had caused many of the capsules to evert their filament. So that I have not been able, so far, to ascertain the length of the filament in the spores under discussion. Occupying a considerable portion of the sporoplasm is a large, well-

* Woodcock, Proc. L'pool Biol. Soc., Vol. XVIII., p. 140 (1904).

defined vacuole (*i.v.*) which is invariably present. This is the iodinophilous vacuole, which is characteristic of all members of the *Phaenocystes* belonging to the family Myxobolidae. The nucleus in connection with each polar capsule—the nucleus, *i.e.*, of the so-called "capsular cell," or portion of the pansporoblast from which each capsule is formed—is shewn at (*n.p.c.*). The two germ-nuclei of the undivided sporoplasm are visible at (*N*). It may be added that, in one or two instances, I could make out a slightly deeper-staining line or thickening just internal to the spore-wall on either side. These probably represented the nuclear remains of those other portions or organellae of the pansporoblast, which, as recently shewn by Léger and Hesse,* give rise to the two valves of the spore. As, however, I did not feel quite sure of them, owing to the faintness of the staining, and as neither of the spores drawn actually shewed them at all, I have not included them in the figure.

With regard to the systematic position of this parasite of *Gadus esmarkii*, the simple shape of the spore, lacking any tail-processes, makes it apparent that it must be included in the genus *Myxobolus*; and, further, the presence of two practically equal polar capsules places it in the corresponding section of this genus. The dimensions of the spore do not agree at all closely with those of any Myxobolan spore, belonging to this section, which has so far been described. Moreover, up till now no Myxosporidian has been known to occur in one of the Gadidae. Hence it is most probable that this *Myxobolus* is a new species, for which I propose the name *M. esmarkii*.

H. M. W.

* Léger and Hesse, C. R. Ac. Sc., 19th March, 1906.

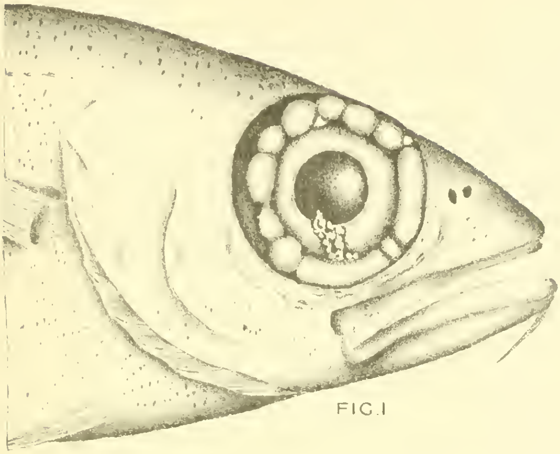


FIG. I

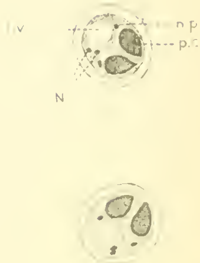


FIG 2

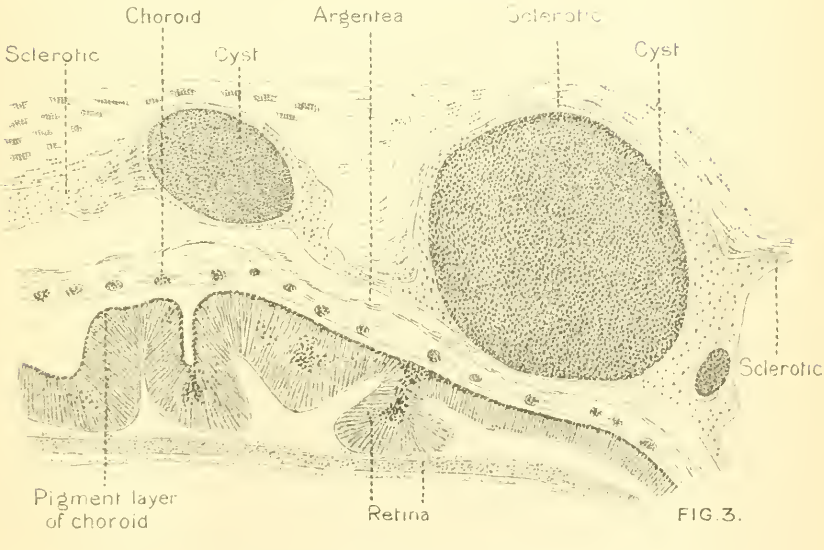


FIG. 3.

MYXOBOLUS ESMARKII

1. Head of Gadus esmarkii with infected eye
2. Spores of M esmarkii.
3. Section of optic bulb with infected sclerotic

Figs 1 & 3. J. Johnstone del
Fig 2. H. M. Woodcock del. *S.B. lith.*

ICHTHYOLOGICAL NOTES.

JAS. JOHNSTONE.

(1) An hermaphrodite hake.

In June last, Mr. W. Wright, a fisherman who had attended the classes at Piel in 1905, recognised that a hake which he was gutting on board a steam trawler, fishing off the West Coast of Ireland, was possessed of hermaphrodite organs. The viscera were, therefore, preserved in some spirituous liquid and handed to Capt. Wignall, who sent the specimen to me. In the course of dissection, which is always a much more rapid process on a steam trawler than in a laboratory, the viscera had suffered considerably, and the relations of the genital ducts, urocyst, and alimentary canal were not at all clear in the specimen when it reached me. Nevertheless, there is no doubt that the organs are those of a hermaphrodite hake.

Both ovaries are present. That on one side is 5·5 × 3·25 cm. in diameter; that on the other side being 6·5 × 3·5 cms. in the corresponding dimensions. They are apparently normal organs, hard, and crowded with small ova, and not dissimilar in structure and stage of ripeness to the ovaries of a normal hake at the same stage of development and at the same period of the year. The ova are about 0·8 mm. in diameter.

At the posterior end of each ovary is a testis. These organs have the shape and appearance characteristic of a well-developed gadoid testis. They are apparently incomplete so I do not give their dimensions. Both are equally well developed, and each is larger than the ovary to which it is attached. They are convoluted in the usual manner though the convolutions are not so

numerous or complex as in a normal male fish. A thick sheet of peritoneum, loaded apparently with fat, connects the two testes. On cutting open the ovaries there was no perceptible lumen, except at the posterior end, where the substance of ovaries and testes became confluent. At this place the lumen of the ovary was continuous with that of the proximal part of the testis.

Cases of hermaphroditism in most teleosts, especially in Gadoid fishes, are, of course, very rare. Nevertheless, a fair number of hermaphrodites have been described. The earlier literature is discussed, and the instances of hermaphrodite codfish cited in the well-known paper by Howes* on the "Hermaphrodite genitalia of a codfish," a further instance as recorded by Ramsay Smith,† and other cases are recorded by Masterman,‡ who discusses the cases recorded later than those in Howes' classical paper. The specimens figured by Howes and Masterman were apparently functional females. Whether or not ripe spermatozoa were extruded by these fishes while alive is difficult to say, but probably the male organs were functionless. In Ramsay Smith's specimen (from a haddock) the testes and ovaries were equally well developed, but the former were relatively larger than in Howes' specimen, where the testis formed a small rosette-shaped structure at the extremity of the ovary. In Masterman's specimens the testes were small and there were a few ripe eggs in the mouth of the oviducts. These fishes were, therefore, probably functional females. In the specimen now before me we have what is probably a functional male fish. The testes are well developed and there is free communication between them and the

* Journal Linnean Society, vol. 23, 1891.

† Rept. Scottish Fishery Bd., vol. 9, p. 352 1891.

Do. do. vol. 12, plates 3 and 4, and vol. 13, p. 297, 1893-

cavities of the ovaries and oviducts. If ripe spermatozoa were extruded these must have been emitted through the (normal) female genital aperture.

In the southern Irish Sea the hake appears to spawn later in the year than its allies. Holt* found ripe specimens as late as July, and concludes that, in the Irish seas, the spawning period of the hake may be prolonged from March until the end of July. Ewart† found that the spawning took place late in the year, and M'Intosh reports a ripe male in August on the East Coast of Scotland. Apparently, then, the fish may spawn about midsummer, and, if so, the hermaphrodite specimen here described was a functional male—that is if the fish were sexually functional at all—for the ovaries were those of a fish which certainly had not spawned during the year when it was caught, and apparently would not have done so had it remained in the sea. On the other hand the testes had all the appearance of nearly ripe functional organs.

It was interesting to note that two or three small pear-shaped bodies possessing all the structure of a testis, were attached to the outside of one of the ovaries some distance from the place where the main testicular mass and that of the ovaries joined.

(2) **Gurnard** (*Trigla gurnardus*) **with malformed lower jaw.**

A small grey gurnard sent me some time ago by Captain Wignall shews an interesting malformation of the lower jaw. The head of this fish is represented in fig. 20. Seen from the side a notch appears to have been cut out from the mouth of the fish, and even without dissection the peculiar appearance is seen to be due to

* Sci. Proc. Roy. Soc. Dublin, vol. 7, p. 401, 1892.

† 7th An. Rept. Scottish Fishery Board, pp. 3, 196, 1889.

the absence, or at least great reduction in the size, of the lower jaw. The upper jaw overhangs the mouth which is reduced to a small crescentic slit on the lower side of the head; both jaws are quite immovable. Whatever food the fish obtained must have been of very small size. There were no recognisable food remains in gut or stomach. Nevertheless the fish appears to be healthy and in good condition.

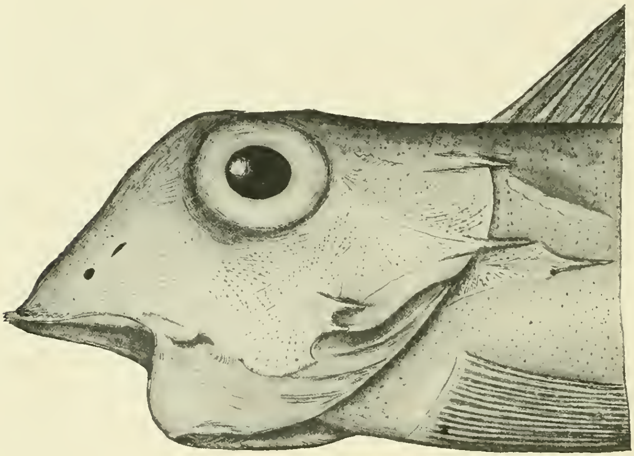


FIG. 20. *Trigla gurnardus.* Natural size.

Fig. 21 represents the normal suspensorium and jaw apparatus of a grey gurnard, and it will be seen that we have here the type which, with no essential variation, is encountered among almost all teleostean fishes. In the abnormal skull now before us (fig. 22), the parts of the suspensorium and upper jaw are essentially as in the normal skeleton. The palato-pterygoid arcade consists of the same bones, and in the same relationships as in the normal skull. So also with the maxilla and pre-maxilla. The palato-pterygoid arcade is, it is true, shifted dorsally

to a position much nearer to the ventral surface of the skull, and this is also the case with the bones of the upper jaw. But otherwise all are quite normal. The difference in the two skulls lies in the lower jaw. In the normal skeleton this consists of the usual parts, dentary, articulare and a very small angulare, and is rather massive. In the abnormal skull these parts are altogether different and are much dwarfed. There is no apparent angulare, but, perhaps this is ossified together with the articulare. This element

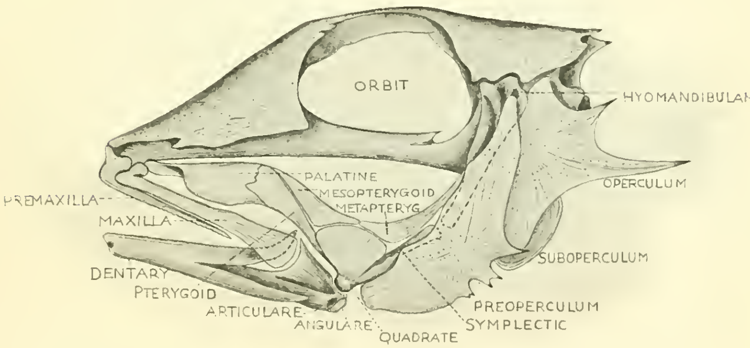


FIG. 21. Skull of *Trigla gurnardus.* Natural size.

is not at all like the normal bone; it is an irregularly shaped bone the long axis of which is dorso-ventral. On its posterior surface is a saddle-shaped articular surface which receives the articular knob of the quadrate. In front and a little above this is a socket-shaped articular surface into which the proximal end of the lower jaw proper fits. The latter consists of an apparently single bone, which is a flat hoop forming the lower margin of the gape. It probably is the fused and completely ossified Meckelian cartilages, whether or not

membrane bones are included in it is not certain, but it probably represents only the two Meckel's cartilages. From these parts, and the articular elements, a strong tendinous and muscular sheet of tissue passes ventrally and is inserted into the hypohyal elements of the hyoid arch. It is the latter which form the prominent "chin" shewn in fig. 20.

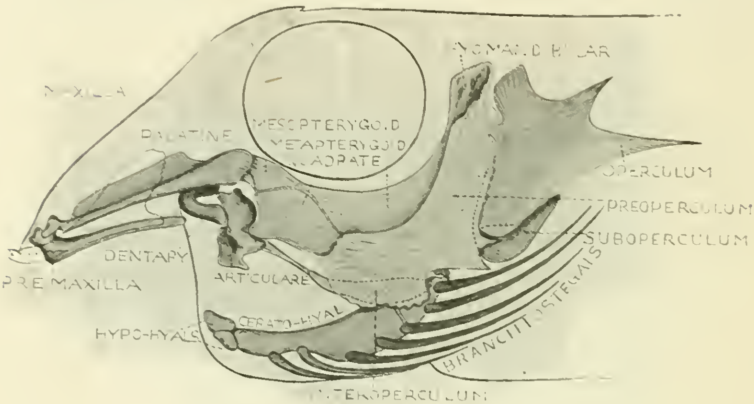


FIG. 22. Malformed skull of *Trigla gurnardus*. Slightly magnified.

Malformations of this kind are extremely rare among teleostean fishes living in nature. Probably individuals exhibiting them are eliminated at an early stage of their life history. If, as is probably the case, the malformation here described was developed during the post larval stage it is difficult to see how the fish contrived to secure enough food. But it is probable that the gape was of greater extent in this stage, and that the very contracted mouth opening was only developed after adult growth had been attained.

Gadus esmarkii, Nilsson.

The Norway Pout, although by no means an infrequent fish in British waters, has not until the spring of this year been recognised on the eastern side of the Irish Sea. Probably it is not uncommon among the shoals of small whiting which at times frequent the shrimping grounds. The specimen referred to here was caught by a shrimper near Morecambe, in March, 1906, and was sent to me by Mr. Ed. Gardner. It was a gravid female, containing ripe ova. Both eyes contained a myxosporidian parasite, which is described above.

Note.—While this report was going through the press Mr Ragdale, Chairman of the Scientific Sub-Committee, noticed in the Manchester fish market a fine specimen of *Beryx splendens*, Lowe, measuring twelve inches from extremity of head to root of tail. It was caught off the S.W. coast of Ireland in Lat. 49° 10′ N. Long. 11° W. The specimen has been presented by Mr. W. Vernon to the Manchester Museum.—W. A. H.

THE FOOD OF FISHES.

By Jas. Johnstone.

Observations on the food of comparatively few fishes have been made. The following lists refer to the examination of the stomachs of 114 plaice and 146 dabs. The observations were made not as part of a systematic scheme for the investigation of the food of fishes in general, but rather with the object of exhibiting the contrast between the food of plaice and dabs caught on the same fishing ground and in the same hauls of the net. I give the numbers of both kinds of fish taken in the hauls; the sizes of the fish are not given, but generally plaice of 9 to 12 inches in length, and dabs of 7 to 10 inches were examined. The contents of the stomach and intestines are given for each fish examined and the observations relating to plaice and dabs caught together are put in parallel columns.

1. Plaice and Dabs.

3rd January, 1906.—Blackpool Closed Ground. Catch: 3 plaice, 77 dabs:—

3 plaice and 6 dabs examined, but all had empty stomachs.

9th January, 1906.—Beaumaris Bay. Catch: 146 plaice, 109 dabs:—

7 plaice.	8 dabs.
4—Empty.	3—Empty.
1—Scrobicularia.	1—Mactra.
1—Solen and Scrobicularia.	1—Mactra and Crangon.
1—An amphipod.	1—Foot of Cardium.
	2—Ophiurids.

20th February, 1906.—"Shoals." Catch: 23 plaice, 29 dabs:—

7 plaice.	14 dabs.
4—Solen.	5—Solen.
2—Solen, Polychaete.	1—Solen, Portunus.
1—Solen, Polychaete, Echinid.	2—Gonoplax.
	1—Nephrops.
	1—Crab.
	1—Gephyrean worm.
	3—Empty.

14th June, 1906.—Tremadoc Bay. Catch: 15 plaice, 24 dabs:—

3 plaice.	6 dabs.
1—Solen, Mactra.	1—Solen.
1—Mactra.	1—Solen, Mactra.
1—Polychaetes.	1—Portunus.
	1—Portunus, Nereids.
	1—Nephrops.
	1—Compound ascidians.

19th June, 1906.—Aberporth Bay. Catch: plaice, dabs:—

12 dabs.

4—Ophiurids (stomachs very full).
1—Ophiurids, Pagurus, Scrobicularia.
1—Scrobicularia, Aphrodite.
1—Scrobicularia, Nucula.
1—Scrobicularia.
1—Pagurus, Scrobicularia, Natica, Aphrodite.
1—Pagurus.
1—Aphrodite, Scrobicularia.
1—Ampelisca (stomach full).

9th July, 1906.—Near Nelson Buoy. Catch: 320 plaice, 126 dabs:—

12 plaice.	10 dabs.
1—Solen.	1—Tubicolous polychaetes.
1—Nucula.	1—Tubicolous polychaetes, Nucula.
1—Tubicolous polychaetes.	1—Ophiurids.
3—Tubicolous polychaetes, Scrobicularia.	3—Ophiurids.
1—Tubicolous polychaetes, Scrobicularia, Nucula.	1—Ophiurids, Nucula.
3—Tubicolous polychaetes, Nucula.	1—Holothurian, Pectinaria.
1—Tubicolous polychaetes, Scrobicularia, ophiurids.	1—Portunus.
1—Empty.	1—Empty.

10th July, 1906.—Off New Quay. Catch: 8 plaice, 16 dabs:—

3 plaice.	6 dabs.
3—Polychaetes.	2—Upogebia.
	2—Hermit crabs.
	1—Ophiurids.
	1—Empty.

13th July, 1906.—Llandudno Bay. Catch: 16 plaice, 84 dabs:—

12 plaice.	12 dabs.
6—Scrobicularia, Nereids.	3—Sabella.
3—Nereids.	3—Sabella, sprats.
2—Nereids, Echinocyamus.	2—Sprats.
1—Solen.	1—Sprats, Crangon.
(Little food in any stomach).	1—Sprats, Actinia.
	2—Portunus.
	(Stomachs full.)

19th September, 1906. Red Wharf Bay. Catch: 5 plaice, 24 dabs:—

3 plaice.	21 dabs.
3—Scrobicularia.	3—Ophiurids.
	1—Ophiurids, Solen.
	1—Ophiurids, Scrobicularia.
	1—Ophiurids, Hermit crab.
	1—Ophiurids, Crangon.
	1—Ophiurids, Ampelisca, Hermit crabs, Echinus.
	2—Scrobicularia, Ampelisca.
	1—Ampelisca, Ophiurids.
	1—Ampelisca, Hermit crab, Ophiurids.
	2—Hermit crabs.
	1—Crangon.
	1—Carcinus.
	5—Empty.

20th September, 1906.—Entrance to Formby Channel. Catch: 22 plaice, 150 dabs.

8 plaice.	11 dabs.
2—Scrobicularia.	1—Tubicolous worms.
2—Scrobicularia, Polychaetes.	2—Tubicolous worms, Mactra.
2—Ophiurids, Polychaetes, Mactra.	1—Tubicolous worms, Venus.
1—Polychaetes, Mactra.	2—Tubicolous worms. Portunus.
1—Empty.	1—Tubicolous worms, Carcinus.
(Very little food in stomachs.)	1—Natica.
	1—Nereids.
	1—Sprat, Ophiurids.
	1—Sprat, crab.
	(Stomachs full.)

2nd October, 1906.—Luce Bay. Catch: 88 plaice, 14 dabs.

22 plaice.

10—Solen.
1—Solen, Nereids, Ampelisca.
2—Solen, Nereids.
1—Solen, Ampelisca.
2—Solen, Nucula, Mactra, Crab.
3—Nereids.
1—Nereids, Ampelisca
1—Arenicola.
2—Empty.

4 dabs.

1—Arenicola.
1—Portunus.
1—Nephrops.
1—Philine, Tube worm.

2nd October, 1906.—Luce Bay. Catch: 21 plaice, 21 dabs:—

6 plaice.

6—All Solen.

6 dabs.

1—Solen.
1—Solen, Pandalus.
1—Solen, Ophioglypha.
1—Solen, Crab.
1—Philine.
1—Gasteropod foot.

2nd October, 1906.—Luce Bay. Catch: 184 plaice, 37 dabs:—

7 plaice.

1—Solen.
1—Solen, Nucula.
1—Solen, Nucula, Nereids.
1—Solen, Nucula, Nereids, Scrobicularia.
1—Nucula.
1—Nucula, Nereids.
1—Nucula, Scrobicularia.

14 dabs.

1—Solen.
3—Ophioglypha.
1—Ophioglypha, Scrobicularia.
1—Ophioglypha, Scrobicularia, Thracia.
1—Ophioglypha, Carcinus.
1—Ophioglypha, Cardium echinatum.
1—Scrobicularia, Crab.
2—Hermit crabs.
1—Portunus.
1—Philine.
1—Nemertine.

5th November, 1906.—Catch: 41 plaice, 32 dabs:—

12 plaice.	15 dabs.
10—Solen.	4—Solen.
2—Solen, Crab appendages.	1—Solen, Nereids, Hermit crabs, Zoophytes.
	1—Hermit crabs, Solen.
	1—Hermit crabs, Amphitrite.
	1—Hermit crabs, Solen, Pecten.
	1—Zoophytes, Solen.
	1—Portunus.
	1—Soft crab.
	4—Empty.

22nd November, 1906.—Near Nelson Buoy. Catch: 10 plaice, 10 dabs:—

9 plaice.	7 dabs.
All empty.	All empty.

It is, of course, only practicable to display these observations in a roughly quantitative manner. The actual numbers of food animals present in the alimentary canal of each fish were not counted, and only approximate estimates of the abundance of each constituent of the food were made. It is, nevertheless, possible to shew roughly what is the commonest food of each fish. In the following table the numbers of black dots represent the number of fishes in which the food animals noted in the adjoining columns occurred exclusively. Each full dot represents two fishes.

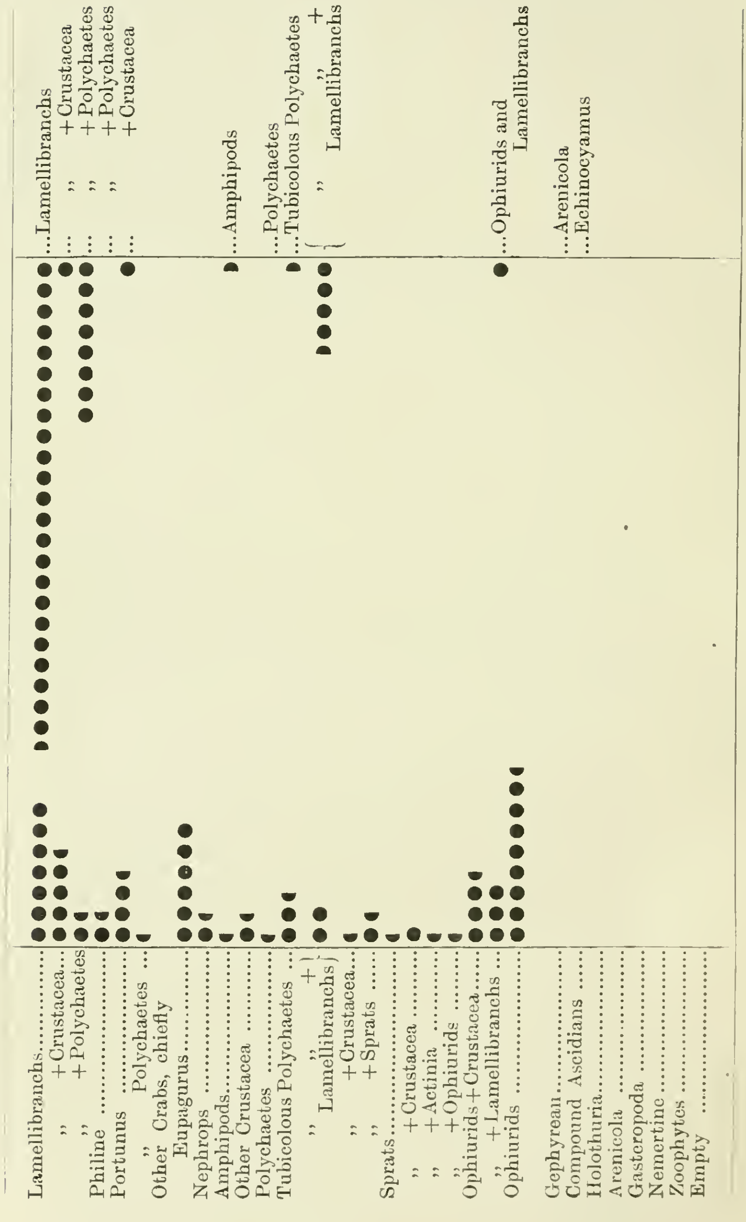


Fig. 23. Food of plaice and dabs.

When arranged in this way the contrast between the food of plaice and dabs is at once evident. We see (1) that the dab is an omnivorous feeder and that it will take anything on the sea bottom from a sprat to a zoophyte; but that (2) it indicates a preference for particular food animals such as ophiurids, crabs and lamellibranchs. The latter were usually *Scrobicularia alba*, *Mactra*, *Tellina*, and often the feet of *Cardium echinatum*. The crabs were either *Portunus depurator*, which often occurred alone in the alimentary canal, *Carcinus moenas*, which was less common, or *Eupagurus bernhardus*, which was, perhaps, the commonest crab found as the food of the dab. The ophiurids were nearly always *Ophiura albida*. The Amphipods were always *Ampelisca*. Sprats were, of course, an unusual food, but on one occasion (in Llandudno Bay, on 13th July, 1906), two dabs were found which were gorged with small sprats. The tubicolous Polychaetes were either *Sabella* or *Amphitrite*. *Upogebia*, a Callianassid Crustacean, which so far we have only found in the stomachs of fishes, was found in two dabs taken on 10th July, 1906, off New Quay Head.

At the foot of the first column in the table are given several animals which occurred exceptionally in the stomachs of dabs examined from various grounds. They were generally associated with other food animals and never occurred in abundance. They indicate further the catholicity of taste of the dab.

The plaice affords a decided contrast. It will be seen that by far the commonest food animals of this fish were lamellibranch mollusca. Next in importance come Polychaete worms which very seldom, apparently, afford an exclusive food for the plaice, but are nearly always associated with lamellibranchs. Both errant and tubicolous polychaetes are eaten. The former are

usually Nereids, and the latter are often *Sabella* and *Pectinaria*. Ophiurids afford a very exceptional food for the plaice. Once or twice *Echinocyamus pusilla* was found, but in association with other animals, usually lamellibranchs. The commoner lamellibranchs are, of course, those eaten by the plaice. The following table represents the order of abundance in which these animals occurred in plaice stomachs:—

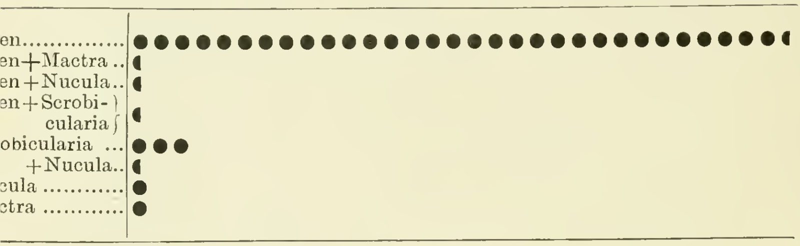


Fig. 24. Food of plaice.

The distribution of plaice and dabs, considered as a bionomic problem is, of course, one which would require much more patient and serious investigation than we have yet been able to attempt. In the consideration of the commoner food animals eaten by each species there is, however, a probable explanation of the comparative ubiquity of the dab as compared with the plaice. The latter is much more fastidious in its tastes than the dab, and when the common bivalve molluscs, which it always prefers, are not present on a fishing ground, or are sanded up, or disappear from any other cause, the plaice deserts this ground in favour of others where these molluscs are to be found. So we find that a "strike," or settlement of the spat of mussels, or other lamellibranchs on any fishing ground is often followed by an extensive immigration of plaice to this spot. Fishermen credit the plaice with the possession of some occult power of detecting the

presence of abundant bivalve food, even at considerable distances, but the reason of these aggregations of plaice on sea bottoms where there is for a time an abundant young lamellibranch fauna is simply this, that plaice are always to some extent moving about, except perhaps during one or more of the colder winter months, and when they encounter accidentally such an abundance of their favourite food they remain in the place where this is to be found deserting it when the food becomes scarce.

On the other hand, the dab, being a greedier feeder, and one accustomed to "take what it can get," finds a more or less abundant table spread for it on almost any of the shallow-water fishing grounds off our coasts. So we find that the dab is much more widely distributed than the plaice, and that when we cannot fish the latter the dab is generally to be obtained.

The sole is again more fastidious than either plaice or dab. The stomachs of these fish caught on the "John Fell" have been examined very often, but the results are not tabulated. One finds, however, that it is comparatively rarely that soles have any food animals in their stomachs other than Polychaete worms. In the varying abundance of the latter we have then one of the causes of the migrations of the sole. Of course, this is not the only cause, but, no doubt, it is one of the most important.

Finally I give the records of the examination of the stomachs of several cod caught during the early part of the year. They shew little beyond what we already know, viz., that the cod feeds largely on fish and crustacea.

Cod.

9th January, 1906.—Beaumaris Bay. One specimen, 33ins. long. Contents of the stomach were:—

3 dragonets;
1 poor-cod;
1 small pleuronectid.

3rd January, 1906.—Blackpool Closed Ground. One specimen, about 33ins. long. Stomach contents:—

33 sprats (or young herrings, species indeterminable).
1 pleuronectid, 8ins. long;
3 pleuronectid, 3ins. long;
6 shrimps;
1 Aphrodite;
1 piece of coal.

24th January, 1906.—Beaumaris Bay. One cod, 30ins. long. Stomach contents:—

6 Carcinus.

31st January, 1906.—Red Wharf Bay. 1 cod, 30ins. long. Stomach contents:—

6 Hermit crabs.

31st January, 1906.—Near Liverpool N.W. Light Ship. Cod, 27ins. long. Stomach contents:—

1 whiting, 10ins long.

Cod 22ins. long. Stomach contents:—

7 Portunus.

Codling, 9ins. long. Stomach contents:—

9 Portunus.

1st February, 1906. Near N. Constable Buoy. Cod 32ins. long. Stomach contents:—

2 flat fishes, 6 to 8ins. long;
1 dragonet;
15 Portunus.

20th February, 1906. Shoals. Cod, 33ins. long.

1 dragonet;
15 Portunus.

20th February, 1906.—Shoals. Cod, 33ins. long. Stomach contents:—

1 poor-cod, much fish debris.

Cod 28ins. long. Stomach contents:—

8 Portunus;
1 small whiting.

Cod 28ins. long. Stomach contents:—

7 Nephrops.

REPORT ON VARIOUS BACTERIOLOGICAL ANALYSES OF MUSSELS FROM LANCASHIRE AND WALES.

By JAS. JOHNSTONE.

1.—ON THE BACTERIOLOGICAL ANALYSIS OF MUSSELS FROM ST. ANNES-ON-THE-SEA.

At the last meeting of the Scientific Sub-Committee in May, 1906, instructions were given to make a bacteriological examination of the mussels on the bed near St. Annes. Accordingly on June 6th, 1906, Dr. Jenkins, Mr. J. Wright and I visited the locality in question and I then collected a sample for analysis.

The sewer at St. Annes is an iron pipe 24 inches in diameter which runs out over the foreshore to the low water mark of ordinary spring tides, and discharges some distance North of the town into the channel known as North Channel or Hollow. The flow of sewage through the pipe is continuous and there is delivered every 24 hours approximately 227,800 gallons (= 25 gallons per head of population). The sewage is quite untreated.

The mussel bed is situated near to, and indeed round, the sewage outfall, and some little distance to the South of the latter. It is a small bed but the mussels on it are fairly abundant. The shellfish are of good quality, with fine, clean and thin shells, apparently rapidly growing fish. Those examined were apparently well-nourished and healthy molluscs. The ground was, at the time when I collected the sample, fairly hard and clean. There were quite a number of starfishes on the bed, and to the presence of these animals is to be ascribed the unusual

number of empty shells present on the ground at the time. We looked for paper or other naked-eye evidence of sewage deposits on the bed but could see little traces of such matter.

This bed has long had an evil reputation and I am informed by Dr. F. Booth, Medical Officer of Health for the Urban District of St. Annes, that though he has no direct evidence of illness in St. Annes resulting from the consumption of these mussels, the Medical Officer of Blackpool has attributed several cases of enteric fever directly to the consumption of mussels from this bed. Unfortunately there is also grave reason for suspecting the cockles from the adjacent foreshore. It is apparently the case that cockles clean themselves of ingested sewage bacilli much less readily than mussels (Klein). That is, these micro-organisms find a more suitable *nidus* in the tissues of the cockle than in those of the mussel.

I think the direction of the tidal streams favours the contamination of these mussels. Not only is there direct and continual pollution by the St. Annes sewer, but a considerable quantity of greatly diluted sewage from Lytham and even from the Ribble Estuary generally, must find its way over these grounds at the earlier period of the ebb-tide. It is true that St. Annes sewage must pass out to sea through the North channel after the higher sand banks have become bared by the ebb, but it is also probable that, with the first of the flood some at least of this sewage may find its way back through the same channel on to the mussel bed. The topography of the coast, indeed, renders it impossible that these shellfish can escape direct contamination.

The sample of mussels for examination was collected about 5 p.m. on 6th June. The mussels were collected from every part of the bed and at once placed in a recently

sterilised, tightly closing paint tin. They were taken back to Liverpool on the same evening and the unopened tins were at once placed in a sink and packed round with fragments of ice. The lids of the tins were tightly closed to prevent ingress of the water resulting from the melting of the ice. Every precaution was thus taken to prevent multiplication of the micro-organisms contained in the shellfish during the interval between collection and analysis. When the tins were opened next day the valves of the mussels were still tightly closed; in the meantime not all the ice had melted.

The primary inoculations were made in the forenoon of June 7th, within 20 hours after collection of the sample. Ten mussels were selected at random from the entire sample. The outside of the shell of each was rapidly washed with tap water (Liverpool water is free from sewage bacteria). The mussel was then opened with a sterile instrument; a slit with a sterile knife was made through the visceral mass into the stomach, and then about 1/10th cc. of the liquid in the latter cavity was withdrawn in a recently-drawn-out glass pipette. This was evenly spread over the surface of a recently poured plate of Grünbaum's neutral-red, bile-salt, lactose agar. At the same time a similar quantity of liquid was taken up in the same pipette and inoculated in a recently boiled tube of sterile milk; a different pipette was used for each mussel. The plates were incubated for 24 hours at a temperature of 42°C. The milk tubes were heated to 78°C. for 20 minutes to destroy vegetative forms of bacteria, and they were then incubated for 24 hours at 42°C. under anaerobic conditions (in an atmosphere of hydrogen).

The results of the primary surface inoculations on the neutral-red agar are given below:—

Mussel.	No. of Colon-like Colonies.	White Colonies.
1	170	12
2	80	4
3	36 with 2 diffuse red patches	7
4	15 with numerous red patches	1
5	76 with many diffuse red patches	1
6	132 with several diffuse red patches	3
7	28 with 5 diffuse red patches	—
8	39 with several diffuse red patches	numerous
9	32 with numerous diffuse red patches	—
10	about 320	—

The significance of these results is that unpolluted mussels or oysters taken far out at sea contain no bacteria in their stomachs which grow on neutral-red agar.

This is also true of non-sterile but uncontaminated sea water. The great majority of the organisms growing on this medium are such as are found in sewage, and indeed are those that have their normal habitat in the human intestine.

The diffuse patches are formed by the fusion of numerous "colon-like" colonies.

The object of the anaerobic milk cultures was to demonstrate the presence of a spore-forming anaerobic bacillus—the *B. enteritidis sporogenes* of Klein, or a nearly related form. All the ten cultures made gave positive reactions; that is, the milk was curdled and abundant gas formation took place, breaking up the curd in the characteristic manner. This again is presumptive evidence of sewage pollution since unpolluted shellfish and unpolluted fresh or sea water do not readily give this reaction.

Bacillus coli, the presence of which is now regarded as indicative of sewage pollution, grows on neutral red agar as deep red, and large colonies. Not all these "colon-like" growths are, however, produced by the typical *B. coli*. Eleven of these colon-like colonies were, therefore, selected from the ten plates, and from them pure sub-cultures were made on nutrient agar. After 24 hours incubation at 42°C. these secondary cultures were examined in detail. The presence or absence of motility of the bacilli was observed microscopically, and each sub-culture was inoculated in 7 different media (bile salt glucose broth, glucose broth, lactose broth, mannite broth, cane sugar broth, glycerine broth, and litmus milk). These tertiary sub-cultures were again incubated for 48 hours at 42°C.

At the end of this time six gave the reactions for the typical *Bacillus coli*. Therefore, about one-half of the discrete colonies identified as "colon-like" proved to be those of *B. coli*.

Neutral-red, bile-salt lactose agar not only affords an easy means of picking out organisms which are probably *B. coli*, but it also distinguishes these from organisms belonging to the Gaertner and typhoid groups. These latter grow on the medium in question as white

translucent colonies. Particular attention was paid to these latter organisms and eight were selected and examined in pure sub-culture as in the case of the "colon-like" colonies.

Most of these colonies were those of aberrant organisms which could not be identified. Two of them gave most of the reactions characterising Gaertner's bacillus, and may possibly have been this microbe. One of them, however, (isolated from mussel No. 2), was of much greater significance, and had the following characters:

1. It formed a round, slightly raised, translucent colony on neutral red, bile-salt, lactose agar.
2. It was motile.
3. It formed acid only in bile-salt broth.
4. Formed acid in glucose broth.
5. Slightly discoloured lactose broth.
6. Formed acid in mannite broth.
7. Gave no reaction with cane sugar broth.
8. Formed acid in milk.

The agglutination test was made for me by Mr. Lewis of the Pathological Department at Liverpool University. Twenty-nine parts of an emulsion of the bacillus were mixed with one part of a serum taken from a patient suffering from enteric fever, and which gave a positive result with a known strain of *Bacillus typhosus*. This was kept under observation for half an hour. At the end of this period well-marked clumping of the bacilli took place.

All these reactions are characteristic of *Bacillus typhosus* the specific germ of enteric fever and I think it highly probable, therefore, that this microbe was present in mussel No. 2.

It is only in comparatively few cases that *B.*

typhosus has been isolated from shellfish, though there is little doubt that it is often present. The microbe is one which possesses little vitality in sea water (Herdman and Boyce), or in the alimentary canal of the mussel or oyster (Klein), and its presence, therefore, indicates recent, and therefore, dangerous pollution, a result which is indeed apparent from the unusually large numbers of *Bacillus coli* present in the mussels examined.

A quantitative analysis of the bacteriology of the mussels was also made (as regards *B. coli*) by the method of decimal dilutions of Dr. A. C. Houston, Bacteriologist to the Royal Commission on Sewage Disposal. Five mussels were taken and removed from their shells with sterile precautions. The liquid from the shell cavities was made into an emulsion with the bodies of the shell-fish and this emulsion was made up to the volume of 500 cc. with sterile water. 1 cc. of this liquid, therefore, contained 1/100th part of one mussel. The liquid was then diluted so that 1 cc. contained 1/1,000 part of one mussel and the process was repeated. In this way emulsions were obtained which contained:—

A. 1/100 part of a mussel.
B. 1/1,000 part of a mussel.
C. 1/10,000 part of a mussel.
D. 1/100,000 part of a mussel.

1 cc. of each was then inoculated on neutral red agar as before, and also in milk under anaerobic conditions.

A contained about 20 colon-like organisms.
B ,, ,, 6 ,, ,,
C ,, ,, 2 ,, ,,
D was sterile.

One of the colonies in C was produced by *B. coli*. This organism was, therefore, present in 1/10,000 part of a mussel (average of five examined).

The enteritidis reaction was given only by emulsion A.

B. coli was, therefore, present in 1/10,000 part of a mussel but was absent in 1/100,000 part.

I think that the above results leave no room for doubt that the mussels from the bed near the St. Annes Sewage Outfall are most gravely polluted by micro-organisms of intestinal (or faecal) origin.

2.—Report on an Examination of the Mussel Beds at Morecambe.

An analysis of mussels from the "Ring-Hole," Morecambe, was made in July of this year, and a Report was presented to the Chairman of the Joint Committee. That Report was only a preliminary one, and was only intended to show whether or not it was desirable to make a more exhaustive examination. It was evident that further enquiry was necessary, and on 15th September, at the time of the low spring tides, Mr. Scott and I visited Morecambe for this purpose. I desire here to state that every assistance was given to us by the Local Sanitary Authority, and that no information that we asked for was withheld. On this first visit we were accompanied by Alderman Thomas Baxter, Alderman Snowden, the Chairman of the Sanitary Committee, Councillor Miller, Inspector Lamb and Mr. E. Gardner, the local Fishery Officer. We saw the sewer outfalls and some of the mussel beds, and collected a number of samples from the vicinity of the main sewer outfalls, from "Baiting-Knot" Skear, and from Ring-Hole. These samples were taken at about 6 p.m., near the time of low water. Again, on 5th October, Mr. Scott and I made another visit to Morecambe and met Dr. Watterson, the

Medical Officer of the Borough. At this time the men were working on the outer Heysham Skears and we therefore visited the latter at 5 a.m., the time of low water on the morning tide. Further samples were taken from "Great-Out" and "Little-Out" Skears, and from Ring-Hole. Samples of sea-water were also taken from off Great-out Skear, from off Baiting-Knot, from over the main sewer outfall (at that time covered), and from Ring-Hole. On this visit we also saw the main sewage culverts and the purification works.

Bacteriological analyses of the shellfish so collected were made in the usual manner. The results show that *Bacillus coli* was present in practically all the mussels examined. But in no case was the degree of contamination considerable. There was a noticeable difference in the results obtained from this analysis and those from the analysis of July 19th. In this latter case the mussels (which we did not personally collect) were apparently not a representative sample from the Morecambe mussel beds, although they may have been taken from a place from which mussels are sent to the markets.

To describe a mussel as dangerously polluted merely because it contains *Bacillus coli* would be quite unjustifiable. This microbe is not, in such circumstances, so far as we know, dangerous to health. Its presence in a shellfish merely indicates that the latter is living in sea-water which is exposed to some degree of sewage contamination. Its presence always indicates the *possibility* that the shellfish in which it is found may, under certain circumstances, come to harbour microbes of a nature strictly pathogenic, such as the typhoid bacillus. But when the number of *B. coli* in a mussel is few then this possibility is remote. When the number is large, or when the pollution is notorious (as in such cases as those of the

mussels at Egremont, Rock Ferry, or St. Annes) then we may reasonably conclude that the shellfish should not be used for human food. In every sample of mussels from the coasts of Lancashire, Cheshire and Wales examined so far, *Bacillus coli* has been found; and much more extensive investigations carried out by the Sewage Commission with reference to oysters have given the same result. "If," say the Commissioners, "it should be seriously contended that the *mere presence* of B. coli or coli-like microbes in an oyster should condemn it, few oysters would probably escape condemnation." Probably the same conclusion holds good for mussels also.

At the present time about 90 per cent. of the sewage of Morecambe is treated by the biological or septic method of purification. The remainder passes into the sea as crude sewage. There can be no doubt that the presence of this crude sewage is objectionable, but I am assured that, in a short time, all the Morecambe sewage will pass through the septic tanks. There is some diversity of opinion among bacteriologists as to how far this method of treatment of crude sewage removes the danger to health which might be incurred should the effluent go near a shellfish laying. But the general opinion is that the chance of dangerous bacteria (such as *Bacillus typhosus*) finding their way into the effluent is greatly lessened.

This is specially the case when the effluent is very largely diluted with sea water before reaching shellfish beds. When the present Morecambe sewerage scheme was sanctioned by the Local Government Board, this was apparently considered, for the main sewage outfall is so situated that the effluent is carried well out to sea and is enormously diluted on the ebb tide before coming near the mussel beds. Shellfish are dangerous to health when they

contain toxic quantities of *Bacillus typhosus* (producing enteric fever), or possibly *B. enteritidis* (producing Gaertner poisoning). These organisms must, in any circumstances, if they are present at all, always be present in sewage in small numbers; and when the latter is intercepted in storage culverts and septic tanks, and then turned into the sea and greatly diluted, the chance that a mussel can be dangerously infected becomes very small.

Most people will say that neither crude sewage, nor a purified effluent, should find its way anywhere near a shellfish bed. One must agree with this opinion, but it is rather to be regarded as a "counsel of perfection." When practicable methods of sanitary engineering and sewage disposal are being considered, and when one thinks of such a densely populated littoral as that of Lancashire, it must be apparent that the ideal of removing sewage so that it cannot approach mussel beds is quite unattainable.

The general conclusion, then, is that the mussels from the skears and beds at Morecambe are not polluted to such an extent as to constitute serious danger to the health of those consuming them for food. In view of the importance of the interests involved, I give below the evidence on which this opinion is based.

The Morecambe Sewage System.

The accompanying chart shows the positions of the mussel beds and the sewer outfalls. Altogether six sewers empty into the Channel. No. I., which lies to the West of the West End Pier, is the main sewer, and carries seawards the treated effluent from the purification works. It is a 24-inch iron pipe, and terminates near the skear called "Seldom Seen," at the low water mark of spring tides. No. II., the "Midland Culvert," is situated to

the East of the old harbour; it serves the Winter Gardens, the Midland Hotel, and a small group of houses near this. No. III., the "Queen Street" sewer, runs out obliquely from Queen Street, near the Central Pier. Nos. IV. and V., the "Calton Terrace" and "Thornton Road" sewers, lie to the East of the Central Pier. No. VI., the "Bare Sewer," is not shown on the chart; it serves the township of Bare. Nos. II. to VI. deliver crude sewage, and Nos. III. to VI. are 12-inch iron pipes. They all terminate at low-water mark of ordinary tides.

Taking a normal population of 11,000 and an average water supply of 20 gallons per head per 24 hours, we find that the main sewer outfall delivers 200,000 gallons of purified sewage, and the other outfalls, 20,000 gallons of crude sewage per 24 hours.

Probably the contribution of the Old Harbour to the pollution of Ring-Hole may be neglected. At the present time the Harbour is strictly private ground, and is used only for breaking up old warships and other superannuated vessels. It is largely silted up, and though the bottom at low water looks exceedingly foul, it is probable that this foulness is more apparent than real. At any rate, the only sewage matters issuing from it are those produced by the workmen employed on the vessels. As a source of pollution the Old Harbour does not count for much, and whatever evil exists could easily be remedied.

Sewers II. to VI. represent the outfalls of the original Morecambe sewerage system before the new scheme was brought into operation. For some years prior to 1897 the Local Government Board had urged on the Borough Council the desirability of adopting a system of sewage purification. In 1897 they expressed the opinion "that untreated sewage should not be discharged anywhere in Morecambe Bay," an ideal which, except at Morecambe,

the Local Sanitary Authorities have not yet attempted to realise. In 1898 Mr. H. Bertram Nichols, C.E., designed the present system of sewerage. At that time the Cameron method of septic purification was in high favour, and it was decided to adopt this. The scheme provided for the collection and treatment of the sewage (almost entirely domestic) of Morecambe, Bare and Torrisholme—an estimated population of 11,000, with an annual influx of 30,000 visitors—at an estimated total cost of £60,000. Really the system was designed to cope with a population of 60,000 persons, and for an average daily water supply of 20 gallons per head. The main sewers are laid along the back of the town, and terminate in two main outfalls, iron pipes of 21-inch and 24-inch diameter respectively. These open into two culverts, which are designed to contain an aggregate night flow of 400,000 gallons. The culverts open into a well, and the sewage, after being screened so as to remove solid matters, is raised by means of four centrifugal pumps worked by electric power to the level of the channels leading into the septic tanks.

There are eight rectangular tanks, each of which is covered in and airtight. After passing through a "detritus chamber," in which much of the grit from road washings is allowed to settle, the sewage passes through special inlet pipes into the tanks themselves. Here it is allowed to remain, and the well-known septic process of purification goes on. The saprophytic and nitrifying bacteria normally present in the stale sewage act on the organic matters present, and most of the solids present in suspension pass into a state of solution. Organic matter is broken down and resolved largely into harmless nitrites and nitrates. A certain amount of sludge settles at the bottom of the septic tanks, but the rate of accumulation of this is very

slow, and the tanks require to be cleaned out only at very long intervals. The result is the production of an effluent which, if the tanks are properly worked, is almost clear, is non-putrescible, and which does not cause a nuisance. The effluent after leaving the septic tanks passes into an underground storage culvert which has a storage capacity of 800,000 gallons. At the outlet end of this storage culvert is a penstock chamber and a chamber provided with a tidal valve. The culvert discharges into a 24-inch iron pipe, the liquid in which is under pressure from the head of sewage in the culvert. The culvert was designed to remain full, or partially full, of effluent for nine hours, and to discharge in three hours. In actual practice the sewer outfall is opened three hours after, and closed four hours before high water.

The main outfall sewer runs out over the sands to a point at Seldom Seen Skear at the low-water mark of spring tides and there discharges. At Morecambe the duration of the ebb is much greater than that of the flood. At spring tides the flood lasts for 3 hours and 15 minutes on the average, and at the neaps for 4 hours and 45 minutes. Extensive float experiments were carried out to determine how far the sewage would be carried by the ebb before the tide turned.* Drift bottles, and large wooden floats provided with flags so that their movement could be observed, were used. The information derived from these float tests showed that the sewage would be carried well out to sea before the turn of the tide, and would not return to Morecambe. Many of the bottles

* The Engineer's report is:—"From information derived from the float tests on the 10th February, and 16th and 23rd March, 1897, and between 25th of August and the 3rd September last (1898), there is no doubt that the best point of discharge is at "Seldom Seen," a point on the north side of the fishing banlks lying north of the Battery Inn. At this point the tide at half-ebb would be sufficient to carry away the sewage coming from Morecambe far out to sea before the tide turned."

were carried out of the Bay entirely and were found at Drigg, on the Cumberland coast. Others went over to Grange, and, no doubt, after oscillating for some time on the ebb and flood would ultimately leave Morecambe Bay. Whatever way the sewage finally went, the dilution in Heysham Lake and the Lune would be enormous. Comparative analyses of the sea-water on the ebb and flood would show, I think, that sewage bacteria though found in the ebb, in the Morecambe Channels, would be absent, or at least very few, in the ensuing flood. It was intended to make these analyses, but the work was too extensive in scope to be undertaken at the time. Such comparative determinations of the numbers of bacilli in sea-water have been made in various places, as, for instance, in the estuary of the Thames and in Kiel Harbour, and the results are both interesting and practically important.

Bacteriological Analyses.

On the occasion of our first visit six samples were collected. Two were taken from near the main sewer outfall, two from Baiting Knot, and two from Ring-Hole. All the samples, with one exception from the top of Baiting Knot, were raked by Mr. Ed. Gardner by means of the "long craam." In each sampling several drags were made, and the total sample was mixed and about a dozen mussels put into a sterilised tin. The tins were placed in ice until the analysis was made (some twelve hours afterwards). Four mussels were then selected at random from each sample--24 in all, and about $\frac{1}{10}$ cc. of the stomach contents of each was plated on neutral-red, bile-salt, lactose agar (Grünbaum's medium). After 48 hours' incubation at 42°C. the plates were examined. Each alternate mussel was also examined for the presence of anærobic spore-bearing bacilli.

The results of these primary inoculations are shown on the following table. It will be seen that the "enteritidis reaction" was typical in each of the 12 anærobic cultures made. The colonies which resembled those produced by *Bacillus coli* were counted, and the numbers present in $\frac{1}{10}$ cc. of the stomach juices of each shellfish vary from 14 downwards. On two of the plates no 'colon-like" colonies were present. In some of the countings the number is to be regarded as a minimum one on account of the fusion of colonies.

1st Analysis.

Primary Cultures on Neutral-red, Bile-salt, Lactose Agar Plates.

Locality.	Mussel.	"Colon-like" Colonies.	White Colonies.	Enteritidis reaction.
Between "Seldom Seen" and "Reap" Skears.	1	3	numerous and fused.	+
"	2	4	"	
"	3	5	1 patch	+
"	4	3 several patches	0	
N. from "Reap" Skear.	5	5	1 patch	+
"	6	4	large patches	
"	7	4	0	+
"	8	2	many patches	
N. Side of "Baiting Knot."	9	3	0	+
"	10	8	2	
"	11	1	2	+
"	12	3	0	
From top of "Baiting Knot."	13	0	numerous fused colonies	+
"	14	3	0	
"	15	0	many patches	+
"	16	0	several patches	
N. Side of "Ring Hole."	17	5 patches	0	+
"	18	5	10	
"	19	2	0	+
"	20	many fused 0	several patches	
Top end of "Ring Hole."	21	7	0	+
"	22	4	numerous and fused.	
"	23	9	0	+
"	24	14	0	

Thirteen of the colonies identified as belonging to the colon group were then subcultured on nutrient agar in sloped tubes, and after 48 hours' incubation these growths were subcultured in bile-salt broth, glucose, lactose, mannose, and cane sugar broths, and in litmus milk. Again, after 48 hours' incubation the cultures were examined. The results of these tertiary subcultures are shown on the next table. It is obvious that the colonies Nos. 6 and 14 are not those of *B. coli.* In two cases (7 and 11) the bacilli were non-motile, and in three cases (1, 6, 7,) the motility was very feeble. But at least six out of the thirteen colonies examined in detail proved to be those of typical *B. coli.*

The white colonies present on the primary plates did not belong to bacteria possessing any special significance.

1st Analysis.

Results of Tertiary Subcultures from Primary Plates.

Mussel.	Bile-Salt.	Glucose.	Lactose.	Mannose.	Cane Sugar.	Milk.	Motility.
1	a g	a g	a g	a g	o	a c	? +
2	a g	a g	a g	a g	a g	a	+
3	a g	a g	a g	a g	o	a c	+
6	a g	a g	a g	a g	o	a c	? +
6	a g	a g	o	a g	o	o	+
7	a g	a g	a g	a g	o	a c	+
7	a g	a g	a g	a g	a g	a c	—
7	a g	a g	a g	a g	o	a c	? +
7	a g	a g	a g	a g	o	a c	+
9	a g	a g	a g	a g	d	a c	+
11	a g	a g	a g	a g	o	a c	—
14	a	a	a	a	o	a c	+
23	a g	a g	a g	a g	a g	a c	+

Explanation of Symbols:—

a = acid; g = gas; c = clot; d = discolouration.

The second analysis was conducted in precisely the same manner. A sample of about 20 mussels was collected from Great-out and Little-out Skears, one mussel being taken from each part of the skears visited. This sample was therefore a thoroughly representative one. One drag was then made in the middle of Ring-Hole, and a similar quantity was taken from the sample. Five mussels from each of these samples were examined as before. In the case of the Ring-Hole shellfish the enteritidis reaction was not tried for. The results of these primary inoculations are shown on the next table. Distinctive white colonies were absent in each case, and the numbers of colon-like colonies vary from 20 downwards. In the case of two of the Outer Skear mussels the enteritidis reaction was atypical.

2nd Analysis.

Primary Subcultures on Neutral-red, Bile-salt, Lactose Agar Plates.

Locality.	Mussel.	"Colon-like" Colonies.	White Colonies.	Enteritidis re-action.
"Ring Hole"	1	about 20	0	
"	2	" 20	0	
"	3	14	0	
"	4	9	0	
"	5	7 some patches	0	
"Out" Skears	6	4	0	not typical
"	7	7	0	+
"	8	16	0	not typical
"	9	7 some patches	0	+
"	10	14	0	+

As before, a number of the colon-like colonies from the primary plates made from the Outer Skear mussels were subcultured. The results are given below in detail. It is evident that colonies 8, 9, 9, 10, 10, are not those of *B. coli*, while there are other four in which motility was not observed. Four colonies are those of typical *B. coli*. This is a lower proportion than was observed in the case of mussels taken from the skears higher up the Channel, and therefore nearer to the sewer outfalls. It is what one might expect to find. The contamination of the outer Heysham Skears is less than that of Baiting Knot and Ring-Hole. By the time that the sewage reaches the Heysham Skears it has become so greatly diluted that there is a much less chance of sewage bacteria being ingested by the shellfish. The percentage of microbes indubitably identified as *B. coli* is also less, an indication that the micro-organism undergoes some change as a result of its sojourn in sea-water, or perhaps perishes altogether.

2nd Analysis.

Results of Tertiary Subcultures from Primary Plates.

Mussel.	Bile-Salt.	Glucose.	Lactose.	Mannose.	Cane Sugar.	Milk.	Motility.
6	a g	a g	a g	a g	d	a c	+
6	a g	a g	a g	a g	d	a c	+
7	a g	a g	a g	a g	o	a c	+
7	a g	a g	a g	a g	o	a c	—
8	o	o	o	o	o	a c	+
8	a g	a g	a g	a g	o	a c	—
8	a g	a g	a g	a g	o	a c	+
8	a g	a g	a g	a g	o	a c	—
9	a g	a g	a	a g	o	a c	+
9	a	a	a	a	a	o	—
10	a	a	a	o	o	a c	+
10	a	a	o	o	o	o	+

Tertiary Subcultures from Broth Inoculated with 1 cc. Water.

Locality.	Bile-Salt.	Glucose.	Lactose.	Mannose.	Cane Sugar.	Milk.	Motility.
"Out" Skear	... a g	... a g	... a g	... a g	... o	... a c	... —
"Baiting Knot"	... a g	... a g	... a g	... a g	... d	... a c	... +

It was not possible at the time to make an exhaustive analysis of the sea-water in the vicinity of the skears, but several samples were collected and examined. Sterilised glass-stoppered bottles were filled with water from off Great-out Skear, from just over the main sewer outfall, from near Baiting Knot, and from Ring-Hole. In the cases of the outer skears, and Baiting Knot, only one culture was made from each sample. One cc. of the water was added to bile-salt broth and the latter was incubated. A reaction was then obtained and plates were made from the primary culture. Colonies supposed to be those of *B. coli* were then selected, and examined in pure subculture. In the case of the Baiting Knot sample the colony selected was *B. coli*, but in the case of the colony from the outer skear sample motility was not observed. The microbes present were therefore not typical *Bacillus coli*.

In the case of the water sample from near the main sewer outfall, and from Ring-Hole, a number of dilutions were made, each $\frac{1}{10}$th less concentrated than the one immediately above. One cc. of the original or diluted liquid was put into a sterile Petri dish and neutral red agar at a temperature of 40°C. was poured in and allowed to solidify. After 48 hours' incubation the plates were counted. A dozen plates were made. Only primary inoculations were made. In the case of the water from

near the main sewer outfall 350 colon-like colonies were counted on the plate made from 1 cc. The plates made from ·001 cc. and the lower dilutions were sterile. In the case of the Ring-Hole sample 19 colon-like colonies were counted in the plate made from 1 cc. and 5 from that made from 0·1 cc. The lower dilutions yielded sterile plates.

These observations do not go very far, but they just indicate that the dilution of the effluent and the crude sewage is so very great that the bacteria present become enormously dispersed through the sea. This is indeed what one might expect from a consideration of the topography and tidal currents of the locality.

The results of these water analyses are shown on the following table:—

Bacteriological Analysis of Water Samples.

Locality.	Amount taken.	Reaction in Bile-salt Broth.	No. of "Colon-like" Colonies on neutral-red agar plates.
Off "Great Out" Skear.	1 c.c.	+	
Off "Baiting-Knot"	1 c.c.	+	
"Ring-Hole"	1 c.c.		19
,,	0·1 c.c.		5
,,	0·01 c.c.		sterile
Above Sewer Outfall	1 c.c.		350
,,	·001 c.c.		sterile

The Effect of the Septic Method of Treating Crude Sewage.

A further question remains to be considered in relation to the contamination of the Morecambe mussel beds, viz., the extent to which the biological or septic method of purification reduces the numbers of pathogenic bacteria which may possibly be present in the crude sewage. It will be admitted that the fact that most of the Morecambe crude sewage passes through septic tanks before reaching the sea must have its influence on the interpretation of the bacteriological results. The question of the harmful effects of contamination of the mussels by the effluent from the main sewer outfall in fact turns to some extent on what really happens in the septic tanks. Does the putrefactive process taking place there lead to the elimination of pathogenic bacteria? There are comparatively few observations on this subject, and I may refer here to the principal results obtained.

(1) Dr. A. C. Houston (Bacterial Treatment of Crude Sewage: Third Report: London County Council, No. 501, 1900), inoculated small quantities of unsterilised Crossness crude sewage with various pathogenic bacteria. The cholera bacillus was employed in two experiments, and a number of these vibrios greatly in excess of the number of other micro-organisms present in the sewage was added to 10 cc. of the crude liquid. In one experiment the bacillus lost its vitality in less than a fortnight; and in the other experiment was found in the sewage for nearly four weeks.

Tubes containing Crossness crude sewage were then inoculated with pure cultures of *Bacillus prodigiosus*. In one experiment the bacillus was not recognised in the liquid after sixteen days. Day by day the numbers of

this microbe decreased, showing that crude sewage was an unfavourable medium for its development. In the second experiment it remained alive for ten days, but was not discoverable afterwards.

Staphylococcus pyogenes aureus, a pathogenic microbe occasionally present in raw sewage, was then experimented with. It was found that this organism could persist in crude sewage for at least thirty-eight days. After that time it was no longer recognisable.

Houston's conclusions from these experiments is that the pathogenic bacteria dealt with are capable of retaining their vitality in crude sewage for a considerable time. But he also points out " that the number of the pathogenic germs added to the sewage in these experiments was vastly greater that could conceivably take place under natural conditions, and that, notwithstanding the enormous numbers introduced, there was definite indication of a somewhat rapid decrease in their numbers." (*Ibid.* p. 75.)

(2) MacConkey (Report Royal Commission on Sewage Disposal, 2 (cd.1178), 1902) determined the longevity of *Bacillus typhosus* in various sewage liquids, and found that this microbe did not find a suitable habitat in any of the liquids dealt with. Crude sewage was inoculated with the typhoid bacillus, and it was found that it died out rapidly. In one experiment it disappeared six days after the date of inoculation, and in another was not recognised after the lapse of thirteen days. Effluents from various septic purification processes were also employed, and it was found that these were even more inimical to the life of the bacillus than crude sewage. A portion of Cameron bed effluent (such as we have to deal with at Morecambe) was inoculated with typhoid bacilli to the extent of twelve millions per cc., and at the end of seven days the number of the bacilli had decreased to 200 per cc. MacConkey's

conclusions may be given in his own words:—"The fluids experimented on are inimical to the growth of the *Bacillus typhosus*, and if these pathogenic bacteria find their way into a bacteriological system of treatment they meet with conditions hostile to their multiplication. We know that typhoid bacilli must find their way into the sewage from the excreta of persons suffering from typhoid fever, but they cannot be present in large numbers, and in the various samples of crude sewage which we have examined we have not found any. Therefore it may be concluded that, allowing that these bacilli reach biological beds or septic tanks, they are present in such small numbers, and the conditions are so adverse to their existence, that they will not survive the treatment."

(3) Boyce, MacConkey, Grünbaum and Hill (Report Royal Commission Sewage Disposal 2 (cd. 1178, 1902), p. 87, determined the rate at which the bacilli present in the effluents from various septic processes disappeared when the liquid was filtered through sand or earth. The effluent from a Dibdin bed was passed through four feet of earth, and while flowing on to this filter great numbers of typhoid bacilli were added to it, so that the liquid contained much greater quantities than could possibly have been the case in nature. Twenty-four hours after being added to the filter the typhoid germs could not be detected in the liquid flowing from the former.

(4) These experiments are, however, rather artificial ones and perhaps greater weight is to be attached to an experiment made by Houston (Report Royal Commission Sewage Disposal, 4, Vol. 3 (cd. 1885), 1904, p. 77) with the object of determining to what extent pathogenic bacteria pass through septic tanks and filters. A Cameron tank and contact beds at Leeds were employed in these experiments. Enormous quantities of *Bacillus*

pyocyaneus (the microbe of green pus) were added to the sewage flowing into the septic tanks. The liquid in these was examined three hours after the inoculation and the microbe was then found. The effluent from the contact beds was then examined, and it was found that *Bacillus pyocyaneus* was present in it immediately after the first emptying of the beds. Therefore, the Cameron method of treating sewage did not eliminate these particular microbes. It ought, however, to be remembered that they were present in the original sewage to a relatively enormous extent, and that results obtained from their use do not necessarily apply to the typhoid bacillus.

The conclusion of the Royal Commissioners on Sewage Disposal (Report 4, Vol. I (cd. 1883), 1904, p. xx) on this question may usefully be quoted here. "The treatment of sewage," they say, "according to methods at present in use, cannot be relied upon so to alter its character as to allow of its discharge in the immediate neighbourhood of shellfish layings without incurring considerable risks of disease being communicated by the consumption of shellfish taken from such layings. In such cases the sewer outfall must be removed or the layings closed. In other cases where (*e.g.*) the layings are at a considerable distance from the outfall, and the sewage would be largely diluted before reaching them, treatment of the sewage might be of value in diminishing risk."

In the case of the Morecambe mussel beds we have seen that this latter condition is satisfied in so far as the main sewer outfall is concerned. Given good administration, and supposing that the taking of shellfish from the immediate neighbourhood of the outfall is not practised, then it appears that this enormous dilution of the effluent does take place. Danger (if such exists) is to be apprehended from the continued existence of the discharge of

crude sewage from the old outfall sewers. I am assured that it is the intention of the Borough Council gradually to connect up the private sewers opening into these main outfalls with the main sewerage system. Already the Queen Street and Calton Terrace sewer systems are in hand, and soon these will be discontinued. There remain then the Midland, Thornton Road and Bare sewer systems. These deliver the sewage from property equivalent to about 200 houses, say 1,000 persons, less than 10 per cent. of the estimated population. This sewage is not included in the present purification systems. When it is ultimately so included, there is no doubt that the present degree of risk would be largely minimised, perhaps practically removed.

3.—Report on an Examination of the Mussel Beds in the Estuary of the Conway.

On August 15th, 1906, a preliminary report was made to the Scientific Sub-Committee on a bacteriological analysis of two samples of mussels sent to me from the estuary of the Conway. It was, however, considered desirable that a more exhaustive analysis and inspection should be made, and on October 17th Dr. Jenkins and I visited Conway for the purpose of seeing the mussel beds. We were accompanied by Dr. Fraser, Medical Officer of Health for the Carnarvon Combined Sanitary Districts, Professor White, of Bangor University College, and Mr. R. Jones, the Fishery Officer in charge of the District. On this occasion we saw most of the sewer outfalls, and also collected samples of mussels from various places, where men and women were working. Samples of water from the river were also taken. It was found impossible to finish the inspection on that day, and on October 26th

Mr. A. Scott and I landed from the "John Fell," met Mr. R. Jones, and saw the remainder of the sewer outfalls, and took further samples of mussels and sea-water. Finally, on October 30th, I visited Llandudno and saw the sewer outfalls there. I am obliged to Mr. Delamotte, Surveyor for the Borough of Conway, and to Mr. W. Little, Sanitary Inspector for Llandudno, for much assistance with regard to the inspection of the sewer outfalls.

The results of these visits, and those of the analyses made, show, I think, that there is some considerable degree of pollution in the mussels of the Conway Estuary, both from the river between the Bridges and Deganwy and from the Scars below the latter locality. The pollution is not excessive, and is far less than that found in mussels from some other places in the Lancashire and Western Sea-Fisheries District, as, for instance, Egremont in the Mersey; though it is greater than in some other mussel areas, as for instance, Morecambe. The area over which the mussel beds and the sewer outfalls are distributed is a comparatively small one, and the pollution is from crude sewage and is of recent origin. It is probable, then, that even the limited degree of contamination of these shellfish, which has been observed, is of some significance.

I do not think that, on the present evidence, the pollution can be regarded as so dangerous as to necessitate drastic measures. To justify interference with this particular industry, topographical and bacteriological evidence, indicating more serious pollution, would be required. It is also an insufficient statement merely to say that mussels derived from (say) the estuary of the Conway had produced enteric fever in (say) Manchester. All other possibilities of contamination between the date

of gathering from the mussel beds and that of consumption would have to be excluded. It is well known that mussels are sometimes kept by the dealers for a considerable time before being sold. Thus an enquiry into a case of ptomaine poisoning in Liverpool some years ago showed that an interval of seven days had elapsed between the dates of gathering and collection, and nine days between gathering and the death of the person consuming the mussels. In the course of a period of this duration, or even of less, the possibility of contamination of mussels, from sources other than the natural habitat of the shellfish, must be a very real one. Such extraneous contamination is all the more possible when the mussels are stocked by the lower class of dealers.

It may reasonably be urged, however, that the amount of pollution of the Conway mussels is such as to make it most desirable that some measures should be taken to reduce the contamination of the River Conway—and, consequently, of the mussels there—as far as is possible. It will be seen that seven sewers open into the river within a very limited area, and these do not represent all the contributing sources of pollution. In the construction of the existing Conway sewerage systems, as in that of many other sea-side towns, the nearest and most convenient point of discharge into tidal waters has been chosen, without much regard to the possibility of fouling either shellfish beds or foreshore. At Conway the sewage is crude, it flows continuously into the river and in some cases spreads itself over sand or mud flats, producing some contamination of these. Without venturing to express an opinion on points of sanitary engineering, I think it might be quite practicable to take steps which would do away with much of the evil effects of the present sewerage system. The Conway mussel industry is one of

great importance. This will be seen from the following statement supplied by Dr. Jenkins:—

Return of mussels landed at Conway during part of the year 1906:—

Month.		Amount. Cwts.		Value. £	
January	...	2520	...	302½	
February	...	1948	...	234	
March	...	1267	...	137	
April to August	...	—	...	—	(close season)
September	...	3800	...	570	
October ...	..	5820	...	730	

A number of bags of mussels were lying on the beach, packed for export, on the occasion of our first visit. These were consigned to Manchester, Leeds, Huddersfield, Halifax and Nottingham.

The price obtained by the fishermen varies from 2s. to 4s. per cwt. Men and women are employed. The men usually fish from open boats by means of the long rake. The women gather the mussels from the scars by hand. I am informed that many of the women are employed by a local fisherman, who pays them 1s. 3d. per bag, for the mussels obtained.

A considerable revenue is thus yielded by the mussel beds in the Conway river, and it is not unreasonable to suggest that some public expenditure on an improved system of sewage disposal is the duty of the local authority and would be justified in its results.

It has been suggested to me by Mr. Delamotte that a portion of the river might be closed by co-operation with the Harbour Authority. It is true that the contamination is pretty general and affects not only the mussels in the river near the Bridge, but also those in the Channel below Deganwy. But the prohibition of taking mussels from the former locality would at least exclude those shellfish

which are most exposed to sewage pollution. If such action should be decided upon, marks delimiting the proposed closed area could easily be selected. By far the greater portion of the mussels sent to the markets are taken from below Deganwy, and the closing of the upper beds would not be a real hardship.

The Conway Sewerage System.

The positions of the principal sewers are shown on the sketch chart (reduced from one marked by Mr. Delamotte). Seven outfall sewers open into the Conway river between Llandudno Junction and the Ferry. Nos. I. and II. discharge the sewage produced in Conway itself. Nos. III. and IV. supply a small group of houses, including the Conway Union Workhouse, at Morfa, opening into a small stream which flows over a mud flat, and opens into the channel at Bodlondeb Point. On the Deganwy side there are two sewer outfalls. No. V. is situated to the North of the Pier. This outfall formerly terminated some distance above low-water mark, and, as it was producing a nuisance, Dr. Fraser recommended that the pipe should be carried further into the channel, and this has now been done. No. VI. serves Tywyn and opens on the sands some distance above low-water mark. At its extremity the sands are rather foul. No. VII. serves the neighbourhood of Llandudno Junction. It is a large and fairly important outfall, which opens into a little stream which runs over the mud flat South of the London & North Western embankment, and opens into the river immediately above the Bridge. It is carried down some distance from the shore, but terminates far above low-water mark. The stream itself is very foul, and the mud on either side of it is not much better. The mud is very soft, and immediately beneath the surface is black and

smells badly. I should compare this deposit with the sludge in a sewage purification tank—in kind only; of course it is not nearly so foul. No doubt it has become thoroughly permeated with sewage which is there undergoing putrefactive purification, with an accompanying deposition of the amorphous black substance which forms the sludge of a septic tank, and with the liberation of sulphuretted hydrogen, and perhaps marsh gas. Both sewage paper and faecal matter were very much in evidence in this stream and on its banks. Of course, this outfall and area are at some distance from the larger mussel beds, but it must contribute to the pollution of the rivers.*

In addition to these sources of contamination there must be others further up the Conway river. The sewage of some of the villages in the neighbourhood, such as Llanrwst, Glan Conway and Bettws-y-Coed, must be discharged into the upper reaches of the Conway, and no doubt contribute notably to the pollution of the latter.

The sewers I have referred to all convey crude sewage and discharge continuously into the river. It is true that tidal flap valves are fixed at their ends, but I question whether these fixtures can generally act in preventing the flow of liquid from the pipes when the latter are covered by the flood tide. In some cases the flaps were certainly choked by debris of various kinds and could not have closed. At any rate, the sewers discharge through the period of ebb tide and for a considerable part of the flood, since their outfalls are mostly well above low-water mark. It is especially near the time of low water, when the volume of the river is small, that the latter becomes

* It will be seen from the Chart that the short stream conveying this sewage into the Conway opens into the latter immediately above the bridge. Mussels are taken from just this part of the river—in fact almost opposite the mouth of the stream referred to.

polluted. For an hour before low water the sewage probably does not pass out to sea and must be carried up the river with the next flood. A considerable volume of polluted water must then simply oscillate up and down the upper reaches of the river, and some of it must pass out on every tide over the mussels at the mouth of the channel.

The population of the Borough of Conway is about 5,000. Taking the usual constant of water supply of 25 gallons per head for 24 hours, we find that 125,000 gallons of crude sewage is discharged per 24 hours—an estimate which does not include the contribution from the population further up the river.

It was suggested to us during our first visit that the sewage from Llandudno might possibly affect the Conway area. At Llandudno there are three outfall sewers which open out on the foreshore to the South of Great Orme's Head. Two of these outfalls discharge rain and surface land water, and need not be considered. The third conveys the sewage of Llandudno. It consists of two iron pipes which pass out over the sands, supported on piles, to a buoy which is at low-water mark of ordinary tides. These two pipes are connected and have a single outfall. They are shown on the Admiralty Chart (Holyhead to Liverpool —Western Sheet), but I am informed that about two years ago the lower end of the pipe became sanded up, and about 150 yards were added to the length. When I saw this outfall there were absolutely no indications of sewage matters on the foreshore as far down the length of the pipe as we could go. Automatic valves at the end of the pipe and at the penstock chamber at the beach end open and close when the tide turns, not merely when the end of the pipe is bared or covered, but when the stream changes. The sewage is thus discharged only on the ebb

tide. To accommodate the flow when the valve is closed, underground tanks, or culverts, have been constructed, which contain the sewage while the flood tide lasts. Whenever the state of the tide permits, these culverts are regularly scoured by men to prevent the accumulation of sludge. The tide, on the ebb, sets round Great Orme's Head and out to sea, and the sewage is carried in this direction. Mr. Little, Sanitary Inspector of Llandudno, informs me that this course of the sewage can actually be traced by observing the oily-looking appearance of the water as it rises to the surface. The Llandudno sewerage system appears to be remarkably well designed. Of course it might be treated, but in this case the necessity is not so strong. I do not think, therefore, that it can reach Conway Estuary unless very exceptionally, as, for instance, on the very last of the ebb and with the driving force of a strong N.W. wind. In any case, the dilution on the flowing tide would be so enormous that appreciable pollution at Deganwy could hardly occur as the result of Llandudno sewage.

The estimated population of Llandudno is about 10,500, and, taking the water supply as 25 gallons per head, the daily discharge of sewage is about 262,500 gallons. The sewage is untreated.

Bacteriological Analyses.

The methods followed were similar to those employed in the analyses of the Morecambe mussels, except that in the case of the Conway mussel a period of 20 hours only elapsed between the inoculation and counting of the primary plates; this because of the rapid growth of the colonies. The samples were brought back to Liverpool late at night and kept in ice for about 12 hours, when they were examined.

Two separate series of analyses were made. The results of the first (mussels and water collected about 4 p.m., 17th October, 1906), are as follows:—

1st Analysis.

Primary Cultures on Neutral-Red, Bile-salt, Lactose Agar Plates.

Locality.	Mussel.	No. of Colon-like Colonies.	White Colonies.	Enteritidis reaction.
Middle of	1	4	0	+
River below	2	28, 1 large batch	0	
Bridge	3	30, 1 long streak	0	—
	4	26	0	
Off Deganwy just below	5	16 and general fusion	0	+
Pier	6	73	5	
	7	15 and general fusion	0	+
	8	20 and 2 long streaks	1 streak	
Well below	9	45, some fusions	1	+
Deganwy	10	51	1 patch	
	11	38	0	+
	12	15	0	
Opposite Perch in Channel	13	28 (not so typical)	0	+
	14	34	1 patch	
	15	Numerous and fused	0	+
	16	25	0	

In the case of Mussel 3, the milk tube was discoloured.

Fourteen of these colonies identified as "colon-like" were then examined further in pure subculture, with the following results:—

Results of Tertiary Subcultures from Primary Plates.

Mussel.	Bile-salt.	Glucose.	Lactose.	Mannose.	Cane sugar.	Milk.	Motility.
1	a	a	a	a	a	d	+
2	a g	a g	a g	a g	o	a c	+
3	a g	a g	a g	a g	d	a c	+
4	a g	a g	a g	a g	o	a c	+
5	a	a	a	o	a	a	—
6	a g	a g	o	a	a	d	+
7	a g	a	o	a	a	d	?+
8	a g	a g	a g	a g	a g	a c	—
9	a g	a g	a	a g	a	a	+
9	a g	a g	a g	a g	o	a c	+
10	a g	a g	a g	a g	a g	a c	+
11	a g	a g	a g	a g	o	a c	+
11	a g	a g	a g	a g	a	a c	+
12	a g	a g	a g	a g	a g	a c	+

Of these colonies 1, 5, 6, 7, 8 and 9 are not those of *B. coli*. But eight give the reactions which I associate with the typical colon bacillus.

2nd Analysis.

On this occasion only one sample of mussels was collected. The boats were working down below Deganwy and we obtained a freshly raked sample from one of them. Ten mussels were examined as before, with the following results:—

Mussel.	No. of "colon-like" colonies.	No. of white colonies.	Enteritidis reaction.
1	29, 1 large patch	0	+
2	62, several patches	0	
3	51, large fused patch	0	+
4	22	17, several patches	
5	50, 1 patch	2	+
6	19, 1 patch	1	
7	41, several patches	0	+
8	48, some fused streaks	0	
9	22, several patches	0	+
10	34, several large patches	0	

Subcultures of these colonies gave the following results:—

2nd Analysis.

Results of Tertiary Subcultures from Primary Plates.

Mussel.	Bile-salt.	Glucose.	Lactose.	Mannose.	Cane sugar.	Milk.	Motility.
1	a g	a g	a g	a g	a g	a c	+
2	a g	a g	a g	a g	o	a c	+
3	a g	a g	a g	a g	a	a c	+
4	a	a	o	a	a	a	+
5	a	a	o	o	o	o	? +
6	a g	a g	a g	a g	o	a c	+
7	a	a	a	a	a	a c	+
8	a g	a g	a g	a g	o	a c	+
10	a g	a g	a g	a g	a	a c	+

The colony from mussel 4 was a typical white colony. Those from mussels 5 and 7 were "colon-like" colonies. Those from mussels 1, 2, 3, 6, 8 and 10 are typical colon bacilli. The others are not this microbe. Six colonies out of nine are therefore *Bacillus coli.* The white colonies on these and the next series of plates are being studied further.

Sea-water Analyses.

On our first visit two samples of water were taken: one from off the Scar opposite the beach and the other from near the Bridge. These were diluted so that various solutions of different strengths were obtained, and cultures were made in neutral-red, bile-salt, lactose agar. The results are as follows:—

	Amount of original water sample taken.		No. of colon-like colonies.
Off Scar, opposite Perch	1 c.c.	...	16
	0·1 c.c.	...	1
	0·01 c.c.	...	1
	0·001 c.c.	...	sterile
Near Bridge	1 c.c.	...	19
	0·1 c.c.	...	2
	0·01 c.c.	...	sterile
	0·001 c.c.	...	sterile

On our second visit three samples of water were taken: one from below Deganwy, one from off Bodlondeb Point, and one from opposite Conway. The samples were collected in 500 cc. bottles. One cc. was taken from near the top of each bottle, and 1 cc. from the bottom layer. These were examined as before, with the following results:

Source.		No. of colon-like colonies in 1 cc.
Below Deganwy	...	6
,,	...	5
Off Bodlondeb Point	...	31
,, ,,	...	23
Channel, opposite Conway	...	77
,, ,,	...	63

Photographs of these Plates are shown in Pl. III.

These water analyses show some considerable general pollution of the river and channel. The first series was taken about low water of a spring tide and the pollution at Deganwy is noticeable. There is practically no difference in the bacteriological condition of the water at the Bridge and far down the river. This, I take it, is because of the rapid tidal stream which has thoroughly mixed up the water in the river. In the second analysis, however, we see a considerable difference in the degree of contamination of the river water. The nearer the Bridge the greater is the contamination. These samples were taken about an hour before low water on a neap tide, when the velocity of the stream in the river was not so great as on the previous occasion.

It would, of course, be desirable to carry these investigations of the pollution of the river water by sewage bacteria much further than has been possible on these occasions. But so far as they go they indicate the pollution of the river water *from above.* They also show, I think, an undesirable amount of sewage bacteria in the water of the river.

4.—Analysis of Mussels from Roosebeck Inner Scar.

On 28th November, 1906, Mr. A. Scott sent me a sample of mussels from Roosebeck Inner Scar, near Piel, Barrow-in-Furness. At the time of collection the scar was being fished by a few men to the extent of about 60 bags per month. It is of little importance as a source of supply for the public markets, as it is a small scar and is only occasionally fished. But its position is such as would justify one in stating that the shellfish contained on it are reasonably free from pollution. In these circumstances we thought it might be interesting to make a preliminary analysis.

Ten mussels were examined in the usual way and with all necessary precautions. The results are as follows:—

Results of Primary Cultures on Neutral-Red Agar Plates.

Mussel.	"Colon-like" Colonies.	White Colonies.	Enteritidis reaction.
1	20, several patches	0	+
2	45, several patches	0	+
3	9	0	+
4	9	0	+
5	2	0	+
6	24, several patches	0	+
7	28	0	+
8	13	0	+
9	3	0	+
10	9	0	No change.

Ten of these "colon-like" colonies were then selected and cultivated on ordinary nutrient agar, and then tertiary sub-cultures were made. The results of these latter sub-cultures are:—

RESULTS OF TERTIARY SUB-CULTURES.

Mussel.	Bile-salt.	Glucose.	Lactose.	Mannose.	Cane Sugar.	Milk.
1	a g	a g	a g	a g	0	a
2	a g	a g	a g	a g	0	a c
3	a g	a g	a g	a g	0	a c
4	a g	a g	a g	a g	0	a c
5	a	a	a	a	0	a
6	a g	a g	a g	a g	0	a c
8	a g	a g	a g	a g	0	a c
9	a g	a g	a g	a g	0	a c
10	a g	a g	a g	a g	0	a c
10	a g	a g	a g	a g	0	a c

All these colonies, except Nos. 1 and 5, are, therefore, those produced by *Bacillus coli,* or by a very closely allied organism.

CONCLUSION.—The results indicate a certain degree of sewage pollution. This is, indeed, slight—so slight as to be certainly insufficient to justify any degree of interference with the local industry, unless other evidence were forthcoming which might render these bacteriological results of significance. Now it is here that one might expect freedom from sewage contamination. There are only two neighbouring towns, Barrow and Ulverston, the influence of which need be considered, and the situation of these places with respect to Roosebeck Scars is not such as to lead us to expect serious pollution of the latter, especially when the direction of the tidal streams is considered. Nevertheless, sewage bacteria are carried to the mussels. I can only suggest that the sea all along the coast of Lancashire is generally slightly polluted with sewage matters, and that it is this general pollution of the sea water which is the cause of the contamination in cases like the present one.

To what extent does the sea contain sewage bacteria?

Investigations have not, so far, been made in the Irish Sea, and we have thus no means of ascertaining how far the pollution in any specific case is due to this supposed general contamination. It is because one is unable precisely to separate the effects of this general (and probably harmless) contamination from local and always potentially dangerous pollution that there must frequently be difficulty in interpreting such results as this analysis gives. A thorough examination of the distribution of colon bacilli in the coastal waters of Lancashire would undoubtedly be of practical value.

Explanation of Plate and Charts.

Chart V.—Chart of the sea near Morecambe, shewing mussel beds and sewers.

Chart VI—Similar chart of the Conway Estuary.

Plate X. — Three cultures made by inoculating 1 c.c. of river water in neutral red, bile-salt lactose agar. Photograph by A. Scott, slightly reduced.

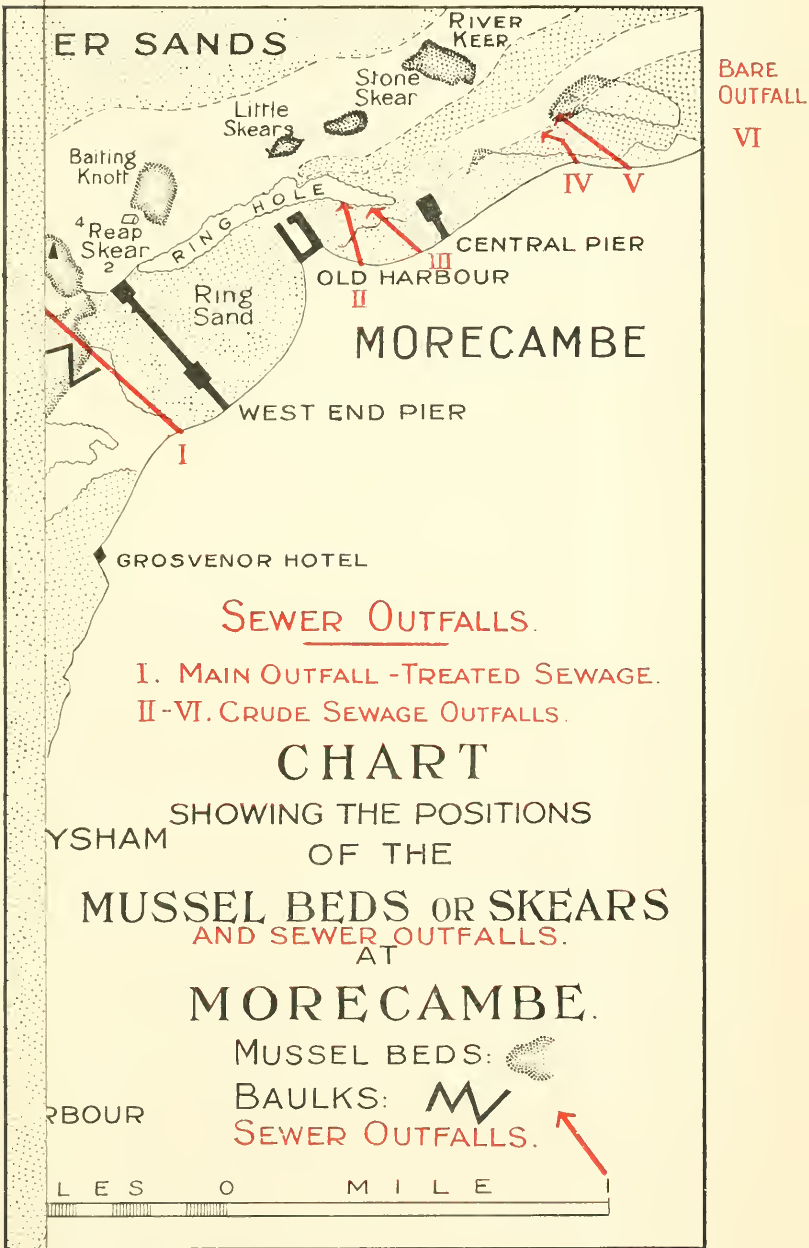
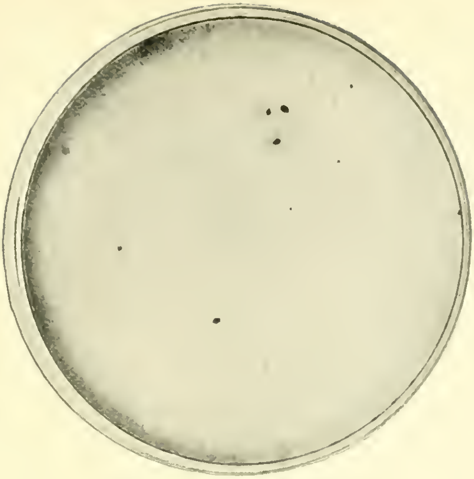
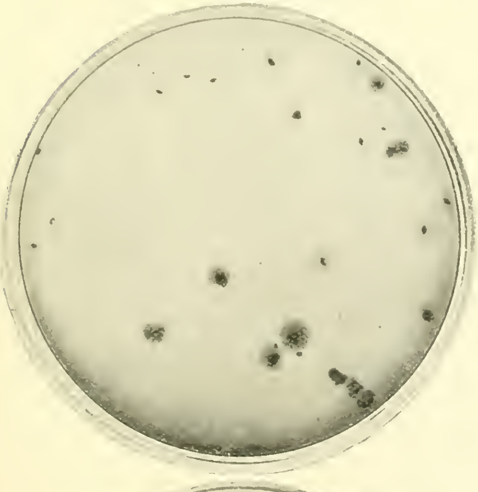

ER SANDS
RIVER KEER
Stone Skear
Little Skears
Baiting Knott
4
Reap Skear
2
RING HOLE
Ring Sand
OLD HARBOUR
CENTRAL PIER
MORECAMBE
WEST END PIER
GROSVENOR HOTEL
BARE OUTFALL
I
II
III
IV
V
VI
SEWER OUTFALLS.
I. MAIN OUTFALL - TREATED SEWAGE.
II - VI. CRUDE SEWAGE OUTFALLS.
CHART
SHOWING THE POSITIONS
OF THE
MUSSEL BEDS OR SKEARS
AND SEWER OUTFALLS.
AT
MORECAMBE.
MUSSEL BEDS:
BAULKS:
SEWER OUTFALLS.
YSHAM
RBOUR
LES 0 MILE 1

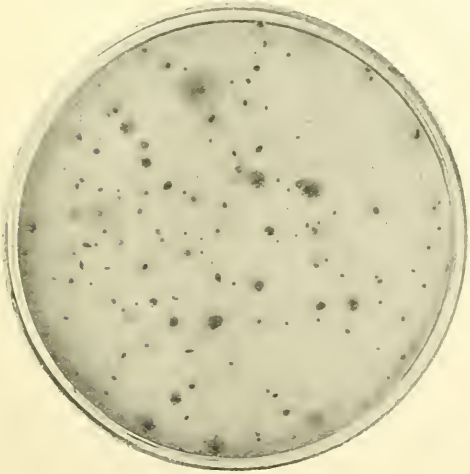
PLATE X.



CONWAY RIVER: 1 cc. water from below Deganwy.



CONWAY RIVER: 1 cc. water from off Bodlondeb Point.



CONWAY RIVER: 1 cc. water from opposite Conway.

L.M.B.C. MEMOIRS.

No. XV. ANTEDON.

BY

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ANTEDON BIFIDA, Pennant (=*Comatula rosacea*, Linck, of Forbes and other authors), is the most familiar example of the Class CRINOIDEA found in British seas. Of the six species of the genus recognised as British, five appear to be confined to the deeper waters of our seas, but *A. bifida* has been recorded from depths of a few fathoms only at many points around our coasts. In the L.M.B.C. district it occurs in large numbers off Cemmaes Bay, North Anglesey, at a depth of 10 fathoms, and also off Bull Bay. It is abundant around the South end of the Isle of Man, and is often found clinging by means of its cirri to the wicker creels used by fishermen for the capture of lobsters and crabs. The fishermen state that specimens are always more numerous on the creels after stormy weather.

With abundant aeration and a moderate amount of light, Antedon may be kept under observation in tanks for months. It is not usually an active animal. By means of its cirri it clings tenaciously to stones, algæ, hydroids, &c., the arms being widely spread horizontally with the tips more or less flexed towards the disc (Pl. I., fig. 1). When disturbed it swims actively and with strikingly graceful movement, the two arms of each pair being invariably flexed and extended alternately (Pl. I.,

fig. 2). The colour of Antedon is very variable. Some specimens are of a deep reddish purple, uniformly distributed over both disc and arms, but the majority are clouded and spotted with rose, orange, and yellow tints. The colouring matter is highly soluble in fresh water, alcohol, and glycerine, but not in ether. Its properties in *Antedon bifida* and other species of the genus have been described by Moseley (**1**), Krukenberg (**2**), and MacMunn (**3**), to whose papers the reader is referred.*

External Characters.

Antedon is composed of a central disc and five pairs of long and flexible arms fringed with pinnules (Pl. I., fig. 2). The disc consists of a shallow cup or calyx, composed of a number of calcareous plates firmly articulated together, and a lenticular visceral mass, lodged within the cavity of the calyx, and containing the central parts of the ambulacral, nervous, and vascular systems in addition to the alimentary canal. A number of jointed appendages called cirri, each terminating in a claw, are attached to the sloping sides of the central plate of the calyx (Pl. I., fig. 3, *ci.*). The opposite face of the disc is the "tegmen calycis" (Pl. II., fig. 24, *tg. cl.*). Near its centre is the mouth (*mth.*), surrounded by five slightly elevated valvular folds (Pl. II., fig. 28, *v.f.*). The tegmen calycis is traversed by five ambulacral grooves, fringed with delicate tentacles (Pl. II., fig. 24, *amb. gr.*), which radiate from the mouth to the edge of the disc and there bifurcate to enter and traverse the entire length of the ten arms and all their pinnules except the first or proximal one (fig. 24). In one of the five interradial

* The black numerals in brackets refer to the list of references given at the end (p. 410).

portions into which the tegmen calycis is divided by the ambulacral grooves there is a conical projection, the anal funnel (Pl. II., fig. 24, *an. fl.*), at the apex of which the anus (*an.*) is situated. The margin of the anal aperture bears minute papillæ. With the aid of a good lens a number of minute pores may be detected in the tegmen calycis. These are the external apertures of the ciliated funnels of the water vascular system.

Orientation.—When Antedon is at rest with the mouth directed upwards and the anal interradius nearest to the observer, it is customary to call the opposite radius anterior. The four remaining radii are thus right anterior, right posterior, left posterior, and left anterior. In correspondence with this designation of the radii the interradii are called right anterior, right postero-lateral, posterior (or anal), left postero-lateral and left anterior respectively. To maintain this orientation when the animal is viewed from the aboral surface the posterior (anal) interradius must be turned away from the observer.

The Skeleton.

The skeleton of the calyx is composed of a centro-dorsal plate (Pl. I., fig. 3; Pl. V., fig. 52; Pl. VI., fig. 59, *cnt. dr.*), to the convex aboral surface of which the cirri are articulated; five radial plates (Pl. V., fig. 52; Pl. VI., fig. 59, *rd.*), which form a pentagon and rest upon the plane oral surface of the centro-dorsal; and five basal plates which are fused together to form a single plate, the rosette (Pl. I., figs 17 and 18; Pl. V., fig. 52; Pl. VI., fig. 59, *ros.*), which roofs over a bowl-shaped cavity in the centro-dorsal (Pl. I., fig. 19). To these must be added, as contributing to the support of the visceral mass, the two most proximal joints of the arms, called respectively the first and second primibrachials (Pl. I., fig. 3; Pl. V.,

fig. 52; Pl. VI., fig. 59, *pmb.* 1 and *pmb.* 2). The latter joint is axillary, and supports, in each radius, two long series of secundibrachials (Pl. I., fig. 3, *sec.*), which form the skeletons of the five pairs of arms, and to these the much shorter series of joints which support the pinnules are articulated.

Several specimens of Antedon with only eight arms have been observed by the writer, and one with twelve was described by Dendy (**4**). The eight-armed condition results from the absence of one of the radii, while the two extra arms of the twelve-armed specimen resulted from the bifurcation of two of the normal ones. In each of these the second secundibrachial became an axillary, similar to the second primibrachials, and of which each facet bore the long series of, in this case tertibrachial, joints forming the arms. In many species of Antedon one or both facets of the primibrachial axillary bear a series of two or three secundibrachial joints, the second or third of which is an axillary, and may in turn bear two or three tertibrachial joints, the second or third of which is also an axillary. In this way the large number of arms borne by many tropical species arise. All the skeletal plates are composed of more or less densely reticulate calcareous matter, to which the name "stereom" has been given. This reticulate structure may be seen in its simplest form in the skeletal plates of the larva (Pl. VI., figs. 66, 67, and 69), in which the reticulations are all in one plane, but in the much more massive plates of the adult they form a sort of sponge work, the meshes of which vary in shape and size even in the same plate.

The Centro-dorsal Plate.—The form of this plate (Pl. I., figs. 3 and 19) resembles that of a shallow bowl. It is of considerable thickness; and its outer margin, as well as that which bounds and slightly overhangs the

comparatively small cavity, is pentagonal, with rounded and slightly upturned angles (fig. 19). In the peripheral portion of the bottom of the cavity may be seen the inner ends of a number of minute canals, through which nerve cords pass to the cirri (Pl. V., fig. 52; Pl. VI., fig. 59). The central portion of the aboral face of the plate is flat or only slightly convex (Pl. I., fig. 20). The peripheral portion is wholly occupied by a number of sockets for the articulation of the cirri. Those which border the flattened central portion of the plate have a nearly circular outline, while the more peripheral ones become more or less angular, owing to close approximation. At the bottom of each socket there is a minute papilliform elevation, perforated in its centre by the external opening of one of the canals already mentioned. The oral face of the plate is nearly flat. Shallow grooves traverse it at the interradial angles from the periphery to the margin of the cavity, marking it out into five equal and radial segments (fig. 19).

The Cirri.—These vary in number from twenty to nearly forty. Each cirrus (Pl. I., fig. 3; Pl. III., fig. 38) is composed of from ten to eighteen calcareous joints, the terminal one being in the form of a claw, immovably articulated with the penultimate joint. The proximal and next succeeding joints are cylindrical and shorter than the remainder, which are compressed from side to side and slightly constricted about the middle of their length, the latter character becoming less marked, almost to disappearance, in the terminal joints. A minute canal, continuous with one of the canals of the centro-dorsal plate, traverses the whole series of joints and ends blindly in the terminal claw (fig. 38, *ax. cn.*). All the joints, except the penultimate and terminal ones, are united by elastic ligaments, and the interarticular spaces

between the joints are widest on the side nearest the vertical axis of the animal, towards which the whole cirrus is always more or less flexed.

Radial Plates.—These plates (Pl. V., fig. 52; Pl. VI., figs. 56 and 59, *rd.*), closely adhering to each other by their lateral faces and together forming a well marked pentagon, are also adherent by their aboral faces (figs. 52 and 59) to the oral face of the centro-dorsal plate. Each radial plate is of triangular form. Its slightly truncated apex, forming the internal face of the plate (Pl. I., fig. 4), is turned towards the vertical axis of the animal, its base forms one of the sides of the radial pentagon, while its lateral faces are in close contact with its fellows on either side. The lateral faces are flat, and each presents a fairly large aperture in the angle formed by the aboral and internal faces (fig. 6). Two apertures of slightly larger size appear in the latter face, which is small and irregular (fig. 4). The external face (fig 5) presents an oval aperture in the middle of its width, and a well marked transverse ridge divides this face into upper and lower portions. The former is divided into two pairs of fossæ by an incomplete transverse ridge and the continuation of two converging ridges, which are more conspicuous on the oral face of the plate (fig. 7). The upper, deeper pair lodge the proximal ends of the powerful flexor muscles, while the lower, shallow pair afford attachment for the proximal ends of the inter-articular ligaments. The lower (aboral) portion of this face is occupied by a single fossa which lodges the proximal ends of an elastic extensor ligament. The oral face of the plate presents two curved ridges (fig. 7), the shorter ends of which approach each other along the median line and form the median edges of the pair of fossæ which lodge the flexor muscles. The apertures

on the external, internal, and lateral faces of the radial plates belong to a system of canals which radiate from the central funnel-like space enclosed by the five plates, and also form an annulus around it. These canals lodge the radial cords and commissures of the apical nervous system, and their courses will be more readily understood in relation to that system.

The Rosette.—This plate (Pl. I., figs. 17 and 18) assumes the form of a disc with a circular aperture in the centre, and a margin divided by deep clefts into ten radiating processes. Of the latter, five are triangular and lie in nearly the same horizontal plane as the disc (fig. 8); whilst the alternating five have nearly parallel margins, which are inflected in such a way as to form a shallow groove, the whole process being markedly reflected in the direction of the centro-dorsal plate. The exact form of the rosette can only be made out after dissociation from the radial pentagon by maceration in a solution of caustic potash. When in situ it almost completely shuts off the funnel-shaped cavity enclosed by the five radials from the cavity of the centro-dorsal plate, the circular aperture in its centre being the only communication (Pl. V., fig. 52; Pl. VI., fig. 59). The five triangular processes are interradial, that is to say, they are directed towards the sutures between the radials; the alternating processes are radial, and abut upon the axial faces of the radials, from which also a number of irregular calcareous outgrowths pass to the oral face of the rosette (Pl. VI., fig. 59).

First Primibrachial Plates.—Each of these is an ellipsoid disc-like plate of moderate thickness (Pl. I., fig. 3, *pmb.* 1; figs. 8 and 9), having two nearly parallel faces, of which the inner, or axial, has much the larger area (fig. 8), and articulates with the outer, or

abaxial, face of the corresponding radial. The axial face is divided transversely by a well-marked ridge into two portions of unequal size. The larger portion is on the oral, or upper, side of the ridge, and is sub-divided by a median vertical and two oblique and less prominent ridges into two pairs of fossæ, of which the upper pair are the deeper. The smaller portion of the face is on the aboral, or lower, side of the ridge, and is wholly occupied by a broad and deep fossa. At the point of intersection of the transverse, vertical, and oblique ridges is the oval opening of a canal which traverses the plate from face to face. The smaller abaxial face (fig. 9) is of simpler character, and presents only one pair of fossæ, divided by a vertical ridge which passes round the opening of the above-mentioned canal, and at its upper, or oral, end is continuous with a slightly raised margin, which bounds the fossæ above. The oral margin of the plate presents a well-marked notch when viewed from this face.

Second Primibrachial Plates.—These plates resemble the radials in general form (Pl. I., fig. 3, *pmb.* 2; figs. 10 and 11). Each one presents a triangular figure when viewed from above or below, and has three articular faces. Of these, the axial closely resembles the abaxial face of the first primibrachial, with which it is articulated, having a single pair of lateral fossæ divided by a vertical ridge, which also passes round the transversely oval aperture of the axial canal. The surfaces of the lateral fossæ slope away slightly from the vertical ridge, so that when the latter is in close contact with the corresponding ridge of the first primibrachial the second primibrachial has a slight range of lateral movement upon the first. A median crest and a pair of divergent lamellæ project from the upper, or oral, margin of the axial face to form parts of the two oblique surfaces of articulation (fig. 11).

In general plan these latter correspond with the articular faces of the radials and first primibrachials, there being a strong transverse ridge that separates a deep fossa on its aboral side from two pairs of fossæ on its oral side (fig. 10). The divergent lamellæ described above form vertical dividing ridges between the latter. The radial canal, which has been seen above to traverse the first primibrachial, enters the second and immediately bifurcates, and the oval apertures of its two branches appear on the corresponding oblique articular faces at the point where the transverse ridge is joined by the vertical one.

Interradial Plates.—In some specimens of Antedon three or four small interradial plates are found in the interradii between the axillaries.

The Arms.—The arms (Pl. I., figs. 1, 2 and 3) are rather slender and taper gradually to extreme tenuity. Each arm is composed of a long series of joints or segments (figs. 3 and 21), placed end to end and bound together by muscular and ligamentous fibres (Pl. V., fig. 50). These segments are termed secundibrachials, and are of the same fundamental form throughout the length of the arm, each one being a short cylindrical rod, traversed by a minute axial canal (figs. 12 to 16, also fig. 21). The absolute length of the segments decreases very gradually from the base to the tip of the arm, those at the latter extremity being rather more than half the length of those at the former. The proportion of length to diameter presents considerable variation. Thus, at the proximal end of the arm the length of the first few segments is less than half their diameter; in the middle region their length is less than twice their diameter; while at the distal extremity of the arm the segments become more and more cylindrical in form, and their length is at least four times their diameter. Viewed from the aboral

surface the outer margins of the first secundibrachials (Pl. I., fig. 3) are seen to be considerably longer than the inner, so much so that the angle of about 80° at which their proximal articular faces incline towards each other is widened out to one of about 130° between their distal faces. The outer margin of the second joint also is longer than the inner, and presents a shallow socket divided by a transverse ridge, in which a minute perforation appears. To this socket the first (oral) pinnule is articulated (fig. 3). With certain exceptions to be presently described, the succeeding joints present a similar inequality in the length of their margins, but the longer margin is alternately outer and inner, and the pinnule borne by every such joint is articulated to it. Hence, when viewed from the dorsal surface, the joints present the appearance of triangles, the apices of which point alternately to one side and the other (fig. 3). In the middle and more distal parts of the arm the inequality of the margins becomes less and less marked; and while in the proximal portion of the arm the articular socket of the pinnule encroaches upon the distal articular socket of the segment (fig. 14), in the middle and distal portions it is more and more restricted to the lateral face (fig. 15). The articular faces of the great majority of the secundibrachial segments present very similar characteristics (figs. 12 to 16). A transverse ridge, pierced by the opening of the axial canal, crosses each more or less obliquely and separates a single deep fossa on its dorsal side from a pair of shallower ventro-lateral fossæ. A pair of radial lamellæ separates the latter from a second pair of fossæ, which are deeper, occupy the ventral portion of the articular face, and are themselves separated by a median and more or less vertical lamella. The single dorsal fossa lodges the elastic ligament which extends the arm; the

ventro-lateral ones lodge the inter-articular ligaments; while the ventral pair lodge the flexor muscles. Actual contact between the successive segments of the arm occurs only along the great transverse ridges. The distal articular face of the first secundibrachial and the proximal articular face of the second resemble the proximal face of the second primibrachial and the distal face of the first in having a vertical ridge separating a single pair of lateral fossæ.

Exceptions to this general rule are presented by the distal faces of certain segments and the proximal faces of the next succeeding ones, which are almost flat, and the articular and muscular fossæ are replaced by a series of slightly elevated ridges and alternating furrows, which radiate from the opening of the axial canal to the dorsal and lateral margins (Pl. I., fig. 16). Ligamentous fibres only (Pl. V., fig. 50) bind the two apposed faces together. To this close and immovable union of two segments, the direction of which is always at right angles to the axis of the arm, the name syzygy was given by Joh. Müller (Pl. I., fig. 3, *syz.*). Of the two segments concerned in the formation of a syzygy only the distal one (epizygal) bears a pinnule, the proximal (hypozygal) never has one. In *Antedon bifida* syzygies occur between joints 3 and 4, 9 and 10, 14 and 15, and then between every fourth and fifth or sixth and seventh. Syzygies appear to be points of least resistance, at which autotomy very frequently occurs.

A transverse interbrachial muscle runs from arm to arm of each pair, and its two ends are lodged in corresponding rounded fossæ excavated in the inner ends of the proximal faces of the first primibrachials (Pl. I., fig. 12).

The pinnules, like the arms, are composed of articulated segments, the diameter of which gradually

decreases from the base to the tip (Pl. I., fig. 3; Pl. II., fig. 24; Pl. III., figs. 32 and 33). The penultimate and terminal segments are armed with minute hooks (Pl. III., fig. 34). The axial canal which traverses the arm branches into all the pinnules and ends blindly in the terminal segment of each. The movements of the pinnules are effected by flexor muscles lodged in deep notches in the ventral margin of each articular face, and extensor fibres which pass from segment to segment on the dorsal margin. Ligamentous fibres only bind the proximal segment to the brachial segment that bears it. The pinnules borne by the second brachial segments are usually twice the length of the succeeding ones, and are distinguished as the oral pinnules (Pl. I., fig. 3; Pl. II., fig. 24; Pl. III., fig. 32). They have no tentacles and no ambulacral grooves, and during life are found more or less strongly flexed over the tegmen calycis (fig. 24). The next pair are quite short, but the succeeding pairs gradually increase in length until the middle portion of the arm is reached, beyond which the length decreases to its distal end or growing point. Dichotomous division occurs repeatedly at the latter, and one branch, on the right and left sides alternately, remains short and constitutes a pinnule.

The external surface of the disc and arms is everywhere invested by a delicate cuticle, beneath which the cells of the ectoderm are distinguishable only in the ambulacral grooves, the inner faces of the oral and marginal tentacles, and upon the pinnular tentacles, where they form sensory papillæ.

In other parts, notably along the sides of the arms and the lateral and dorsal surfaces of the visceral mass, the most superficial cells beneath the cuticle have a more or less regular arrangement, but no sharp distinction can

be drawn between those of the ectoderm and those of the cutis, except in young specimens. Where the subjacent tissue is calcified, especially along the dorsal and dorso-lateral surfaces of the apical plates and the brachial segments, they become fusiform and still more regularly arranged, and the delicate filamentous processes into which their basal ends are divided are continuous with similar processes of many of the cells of the deeper layer (Pl. II., fig. 26).

Muscles and Ligaments.

The flexor muscles of the arms and pinnules (Pl. V., figs. 50 and 52, *flx. m.*) consist of large bundles of parallel fibres which have a strong affinity for aniline stains, especially hæmatoxylin. Each fibre has a minute oval nucleus, and is of uniform diameter throughout its length (Pl. III., fig. 36), but it is thicker along one edge than the other, and thus presents a wedge-shaped figure in transverse section. The ends of these fibres are sharply defined. The extensor fibres are of extreme fineness and have less affinity for stains (Pl. III., fig. 35; Pl. V., fig. 50). In longitudinal sections they frequently possess a more or less wavy appearance. Their ends are split up into a variable number of fibrillæ, each of which may be traced into continuity with the cells of the stroma which forms the organic basis of the adjoining ossicles. The nuclei are smaller and rather more rounded than those of the flexor fibres. The fibres which form the interarticular ligaments are not distinguishable from the extensor fibres, and the interarticular fibres of the cirri are of similar character.

Sacculi.

The sacculi (Pl. II., figs. 24 and 28; Pl. III., figs. 32, 33, 34, and 40; Pl. IV., figs. 41 and 47; Pl. V., fig. 52; Pl. VII., figs. 61, 62, 66, 67, 69, and 71, *sac.*) are minute globular or ovate sacs, which occur in great numbers immediately below the external epithelium at the edges of the ambulacral grooves of the disc, arms, and pinnules, and occasionally in small numbers in the wall of the intestine and mesenteries. Along the grooves of the disc they may form a double or even a triple row, and are especially numerous on the outer sides of the proximal ends of the brachial grooves, on the periphery of the disc (fig. 24). Along the arms and pinnules they form a single row, and alternate regularly with the triad groups of tentacles. Each sacculus consists of a delicate limiting membrane of connective tissue, lodged in the mesoderm and having no permanent aperture (Pl. III., fig. 40). The included space is almost invariably densely crowded with groups of refractive spherules, consisting of an albuminous substance, which are colourless during life, but turn yellow or red after death, owing to absorption of the very soluble pigment of the integument. They have a strong affinity for stains.

These spherules are the product of nucleated cells of pyriform shape (fig. 40, *a*), which clothe the inner face of the lower wall of the sacculus, and are apparently of mesodermal origin. The spherules make their appearance in processes of the cells which grow upwards and finally become attached in the form of filaments to the upper wall of the sacculus. The spherule-containing portion eventually separates from the base of the cell and lies free in the sacculus. Sacculi have been successively regarded as calcigenous glands, mucous glands, excretory

glands, symbiotic algæ, and accumulations of reserve material to be used in the regeneration of injured arms or pinnules. The value of the last view is somewhat vitiated by the fact that sacculi do not occur in the allied genus *Actinometra*, in the injured arms and pinnules of which regeneration goes on quite as actively as in those of *Antedon*. The present writer is inclined to regard the function of the sacculi as excretory.

Digestive System.

The aperture of the mouth does not occupy the centre of the disc, but is more or less displaced in the direction of the anterior radius (Pl. II., fig. 24, *mth.*). It opens into a gradually widening œsophagus, which runs obliquely in the direction of the right posterior radius, and there expands into a large sacculated intestine (Pl. II., fig. 23, *int.*). This, descending towards the aboral face of the visceral mass, and gradually narrowing, makes a complete coil around the vertical axis of the disc in the direction of the hands of a clock. On re-entering the posterior inter-radius it ascends the anal funnel and opens to the exterior through the anal aperture. In addition to numerous short diverticula which open into the intestine in the first third of its course (fig. 23), there are two long ones with finely-branched extremities, which open upon its inner border in the neighbourhood of the left anterior radius (fig. 23, *div.*). The alimentary canal is of almost uniform structure throughout. It consists of an epithelium of fusiform, ciliated cells interspersed, in the œsophagus, with caliciform cells (Pl. II., fig. 25), and, throughout its length, with very minute rounded cells, especially between the basal ends of the fusiform cells. A layer of nerve fibres, continuous with the sub-epithelial nerve ring, underlies the œsophageal epithelium and

gradually thins out as the œsophagus passes into the intestine, in the walls of which it is difficult to trace.

The epithelium and subjacent nerve layer rest upon a delicate basement membrane of connective tissue, which is, however, enormously thickened in the rectal portion of the intestine (Pl. II., fig. 27, *cn. ts.*). Thin but definite layers of muscular fibre form sphincters around the œsophagus and rectum (figs. 25 and 27, *sph. fb.*), but the musculature is elsewhere feebly developed and less definite.

The anal funnel has been observed to contract rhythmically, doubtless in connection with the ejection of water and excreta. The food of *Antedon* consists of diatoms, radiolarians, foraminifera, and other small organisms, which are captured by the tentacle-fringed arms and pinnules and swept down the ambulacral grooves to the mouth by the action of the cilia which line them.

The Blood-vascular or Lacunar System.

This system is highly characteristic of the majority of the Echinoderma, and consists, in *Antedon*, of a number of lacunar spaces, bounded by walls of connective tissue scarcely distinguishable from that which forms the numerous strands and trabeculæ of the body cavity (Pl. V., fig. 52). These lacunæ traverse the body cavity in all directions, and are generally recognisable in sections by their albuminoid contents, which are coagulated by the fixing reagents and may even stain faintly. As will be presently seen, some of the lacunæ simulate true vessels by the assumption of a tubular form and considerable thickening of their walls. The largest and most easily recognisable lacuna is one to which the name 'circumoral blood-vascular

ring' has been given by various authors. It depends into the body-cavity from a point just below the circumoral water vessel (Pl. IV., fig 47; Pl. V., fig. 52, *c.o.bl.r.*), and appears to attain its greatest development in the interradii, especially the anal and right posterior ones. Its wall consists of a thin sheet of connective tissue containing rounded nuclei, and its form in sections depends largely upon the quantity of coagulable fluid contained at the moment of fixation. Generally speaking, however, it may be said to expand gradually and irregularly from its point of attachment to the wall of the œsophagus to its periphery. Here it becomes much more sacculated; and the nuclei are not only more numerous but assume in some parts a definite arrangement.

At one point in its circumference the lacunar walls become thickened, very irregular, and confluent, so as to form a roughly lenticular mass of connective tissue traversed by numerous interlacing tubules. This is the 'spongy organ' (Pl. V., fig. 51). Its tubules are in direct communication with a number of thick-walled trunks (Pl. IV., fig. 45), some of which run directly from the spongy organ to the oral end of the axial organ, and, branching and anastomosing, form a sort of vascular envelope thereon (Pl. V., fig. 52). Others run on alongside the axial organ towards the aboral face of the visceral mass, and there branch and assume more irregular forms upon the internal border of the intestinal coil. Other similar trunks issue from the blood-vascular ring to be distributed around the intestine and in the body cavity, and others to ramify in the substance of the tegmen calycis. Lastly, there is an annular lacuna which lies outside the periphery of the blood-vascular ring and is in communication therewith (Pl. V., fig. 52, *gen. bl. lc.*). From it a thin-walled tubular branch arises in each radius

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to furnish the genital lacunæ of the arms (Pl. IV., fig. 41, *gen. lc.*).

Corpuscles.—Under the term "corpuscles sanguins," Cuénot (**5**) has described three kinds of amœboid cells which occur in the various tissues and cœlomic fluid of *Antedon*: (1) amœbocytes with short pseudopodia; (2) amœbocytes of extremely elongated form which are often found migrating in the tissues, but which ultimately become filled with rod-like bodies which have a special affinity for saffranine, when the cell assumes a rounded form; (3) very slightly amœboid cells crowded with granules which are golden yellow in the living animal. These are the "oil cells" of Wyville Thomson, and they often occur in numbers amongst the cells of the ectoderm, as well as in the stroma of the skeletal plates. The rounded cells described above as occurring amongst the fusiform cells of the intestinal epithelium may possibly belong to the first of these groups.

The Cœlom.

In *Antedon*, as in other Crinoidea, the cavity of the cœlom is not a clear space like that of the Echinoidea and Holothuroidea, but is traversed in all directions by trabeculæ of connective tissue lined by cœlomic endothelium. The cavity is further partitioned by lamellæ of connective tissue which lie parallel to the body-wall into two well-defined but intercommunicating sub-cavities—the peripheral, or subtegumentary, and the peri-intestinal. The latter encloses the intestine, which coils around a central clear space which nearly coincides with the vertical axis of the disc, and is known as the axial sinus (Pl. V., fig. 52, *ax. si.*). The upper, or oral, end of this sinus communicates directly with the subtentacular canals of the arms (fig. 52; Pl. III., fig. 29; Pl. IV., fig. 41, *s.te.ca.*).

The peripheral cavity in like manner communicates with the dorsal or cœliac canals of the same (figs. 29, 41, and 52, *cœ. ca.*). These canals are, therefore, the cœlomic cavities of the arms, and are lined by cœlomic endothelium (fig. 41, *cœ. en.*). They traverse the arms and pinnules to their extremities, and communicate with each other at various points by minute openings in the horizontal and vertical septa which bound them. When viewed in a transverse section of an arm (fig. 29), the dorsal or cœliac canal (*cœ. ca.*) appears as a subtriangular space, bounded dorso-laterally by the flexor muscles and ventrally by a horizontal septum. The latter forms also the dorsal boundary of the subtentacular canals, two quadrant-shaped spaces (*s. te. ca.*) separated by a vertical septum, which, however, disappears before the canals enter the disc. Immediately below the point where the vertical septum merges into the horizontal there is a small rounded or lenticular space, the genital lacuna (fig. 41, *gen. lc.*), which encloses the genital cord or rachis.

Ciliated Pits.—In the median sagittal line of the dorsal wall of the cœliac canal of the pinnules, and immediately above the nerve cord, there are groups of two to six bowl-shaped depressions with slightly raised margins, and lined by modified cells of the cœlomic endothelium (Pl. III., fig. 37, *cil. pt.*). The cells which line the bottom of the depression are flattened and non-ciliated, while those which line the sides are columnar and ciliated. The action of the cilia doubtless serves to promote currents in the cœlomic fluid, and on this account the ciliated pits of *Antedon* have been compared with the ciliated funnels of the Synaptidæ and the ciliated bands in the brachial cavities of the Ophiuroidea. Should this be their only function their comparative rarity in the cœliac canals of the arms is remarkable. Their linear

arrangement, in close proximity to the dorsal nerve cord, is probably not without significance, though no nervous connection between the two has been traced.

The Chambered Organ.

This organ (Pl. V., fig. 52; Pl. VI., figs. 54, 55, 57, 59, *ch. or.*) is a division of the cœlom, and is lodged for the most part in the cavity of the centro-dorsal plate. It consists of five radially situated chambers of roughly equal size, lined by cœlomic endothelium, and completely enveloped on all sides by the central capsule of the apical or aboral nervous system (fig. 57). In the vertical axis, from which the connective tissue septa which divide the chambers spring, there is a column-like prolongation of the axial organ (Pl. V., fig. 52; Pl. VI., fig. 59) which penetrates the central capsule and gradually tapers off in the substance of the centro-dorsal. Tubular extensions of the radial chambers, known as cirrus vessels (figs. 52 and 59, *ci. v.*), enclosed in corresponding extensions of the central capsule, called cirrus cords (*ci. cd.*), and divided throughout by a horizontal septum (figs. 58 and 59) traverse the thickness of the centro-dorsal and the axial canals which have been described above as running through all but the terminal joints of the cirri. The horizontal septa cross the chambers, some to be inserted in the vertical axis (Pl. VI., fig. 59), while others do not reach it. They thus appear in sagittal and tangential sections to divide the aboral ends of the radial chambers into a number of super-imposed spaces. On the other hand, the septa are not continued to the extreme ends of the cirrus canals, so that a circulation of the cœlomic fluid therein is possible.

The Axial Organ.

This organ, variously known as "dorsal organ," "glandular organ," and "genital stolon," has already been seen in connection with the chambered organ (Pl. V., fig. 52; Pl. VI., fig. 59, *ax. or.*). That portion which forms the axis of the latter consists of a comparatively slender cord, traversed by a few tubules lined with epithelium (fig. 59), which finally merge into one in the direction of the centro-dorsal (Pl. VI., figs. 54, 55, and 57, *ax. or.*). In the opposite direction the organ passes through the central foramen of the rosette plate, ascends alongside the axial sinus of the cœlom towards the mouth, and, in the adult animal, ends in a rounded extremity some little distance below the tegmen calycis, in the right anterior radius. This portion of the organ consists of a complex mass of tubules lined with cylindrical epithelium (Pl. IV., fig. 46), and enclosed in a stroma of connective tissue. As already stated above, a part of the lacunar system is in close relation with the axial organ; but the cord-like extensions of its free (oral) end which have been described as passing into the arms of the pentacrinoid larva, there to form the genital rachids, do not persist in the adult. A departure from the structural condition just described appears to be associated with the breeding season. The lumina of the tubules open into one another much more freely than at other times (Pl. IV., fig. 44), and the epithelial cells which line them break away from the basement membrane and become amœboid. Various stages of this process may be seen in serial sections of one and the same organ.

The Water Vascular System.

This system consists of a circum-oral vessel and five radial vessels which spring therefrom and bifurcate at the base of the corresponding pairs of arms to traverse them and their pinnules to their extremities. In addition to these structures there are numerous water tubes which depend from and open into the circum-oral vessel, and still more numerous ciliated funnels which penetrate the tegmen calycis and open into the body cavity.

The circum-oral vessel surrounds the mouth at the base of the oral tentacles (Pl. IV., fig. 47; Pl. V. fig. 52, *c.o.w.v.*). In common with all other parts of the system, it is lined with endothelium, the cells of which are here rounded, non-ciliated, and have a central nucleus which stains faintly (Pl. IV., fig. 47, *cœ. en.*). Longitudinal muscle fibres form a thin but well-defined band upon the side of the vessel nearest to the œsophagus (fig. 47, *l.m.f.*).

Tentacular branches are given off directly to the five interradial groups of oral tentacles, and at these points the lumen of the vessel is traversed by little groups of isolated muscle fibres (*i.m.f.*). Similar groups occur at the points of origin of the radial vessels. The course of the latter coincides exactly with that of the ambulacral grooves of the disc, of the arms, and of the pinnules. A lacuna-like space, the sub-neural sinus (Pl. IV., fig. 41, *s.n.s.*), separates the vessel (Pl. III., fig. 29; Pl. IV., fig. 41; Pl. V., fig. 52, *r.w.v.*) from the sub-epithelial nerve band.

In traversing the arms the radial vessels follow a slightly zigzag course, and give off, at each of the angles, a lateral branch to a corresponding pinnule. Lateral branches are given off also, which, after a short course at right angles to the axis of the arm or pinnule (Pl. III.,

fig. 29; Pl. IV., fig. 41, *tn. vs.*) divide into three to form the cavities of the triad groups of tentacles which spring from a common point in the centre of the lappets which form the margins of the ambulacral groove. Tentacles and tentacular vessels are wanting in the oral pinnules. In its main features the histological structure of these tentacles agrees with that of the oral ones (Pl. IV., fig. 47, *or. tn.*). Passing from within outwards there is (1) an endothelium of rounded cells (*cœ. en.*) lining the lumen of the tentacle and resting upon (2) a thin but well-defined layer of longitudinally disposed muscular fibres (*l.m.f.*) with which the epithelial cells are said to be connected; (3) a layer of connective tissue, scarcely recognisable in the pinnular tentacles; (4) fibrils from the sub-epithelial nerve band (*sb. nv. f.*) (on the inner face of the tentacle only); (5) the external epithelium (ectoderm = *ect.*). In the case of the pinnular tentacles, however, the cells of the external epithelium are grouped together to form stiff projecting sensory papillæ (Pl. III., figs. 30 and 31, *sn. pp.*).

The water-tubes (stone canals of authors), to the number of about thirty in each interradius, open into the circum-oral vessel along its lower side (Pl. IV., fig. 47; Pl. V., fig. 52, *w.t.*). The slightly expanded free ends of the tubes depend and open into the peripheral portion of the cœlom. Their lumina are lined by columnar cells which are ciliated and have large oval nuclei which stain deeply (fig. 47). The ciliated funnels (Pl. II., fig. 22; Pl. V., fig. 52, *cl. fn.*) are scattered all over the tegmen calycis to its extreme edge between the bases of the arms, and are especially numerous along the borders of the ambulacral grooves. Their slightly raised external apertures, the water pores, are visible under a good hand lens. Passing from without inwards the diameter of the

funnel gradually narrows (fig. 22), then widens again to form a median dilatation. Here the columnar cells of the epithelium with which the funnel is lined bear long cilia which, in sections, are invariably directed towards the body cavity. Beyond the dilatation the cells lose their cilia and gradually thin out, until, as the lumen of the funnel gradually narrows, they are replaced by those of the cœlomic endothelium. Occasionally two adjacent funnels unite before opening into the body cavity.

The water-vascular system of *Antedon* and its allies differs functionally from that of the great majority of Echinoderma in having no locomotor rôle. The function of the delicate tentacles which fringe the ambulacral grooves is probably respiratory; and, as will be seen later on, in the description of the nervous system, they are highly sensory. The ciliated funnels and water-tubes probably discharge the same function as the madreporites and water-tubes (stone canals) of the majority of other Echinoderma; but while, in the Echinoidea, Ophiuroidea, and Asteroidea the surrounding water passes directly through the madreporite and water-tube into the water vessels, in *Antedon* it must first enter the body-cavity before passing through the numerous water-tubes into the circum-oral water vessel.

The Nervous Systems.

There are apparently three well-marked nervous systems in *Antedon*, known respectively as the Superficial Oral, the Deeper Oral, and the Apical or Aboral. The first of these consists of a nerve ring encircling the oral aperture (Pl. IV., fig. 47; Pl. V., fig. 52, *c.o.nv.r.*) in close proximity to the circum-oral water vessel, and radial nerves (Pl. III. fig. 29; Pl. IV., fig. 41; Pl. V., fig. 52, *amb. nv.*) which radiate from the ring and traverse the

arms and pinnules to their extremities. The ambulacral grooves are lined with an epithelium composed of fusiform ciliated cells (Pl. IV., figs. 42 and 43), beneath which there is a well-marked band of longitudinally disposed nerve fibres (*amb. nv.*), from which the inner faces of the marginal tentacles are innervated (fig. 41). The band is thickest in the median line of the groove and thins out gradually towards the sides thereof. The filiform basal ends of many of the overlying epithelial cells penetrate the nerve band to the basement membrane upon which it rests (figs. 42 and 43). Scattered between the epithelial cells, just above the nerve band, are many bi-polar and tri-polar cells, which are not improbably in continuity with the epithelial cells and nerve fibres, and similar cells occur in small numbers in the nerve band itself. A layer of nerve fibres extends from the circum-oral ring for some distance along the alimentary canal (Pl. IV., fig. 47; Pl. V., fig. 52, *sb. nv. f.*), but is not readily traceable beyond the œsophagus.

The Deeper Oral system is situated, like the foregoing, on the oral side of the disc and of the arms, but is sub-epithelial in position, and consists of a circum-œsophageal ring with cords radiating from it (Pl. V., fig. 52), lodged in the connective tissue of the tegmen calycis and of the ventral faces of the arms. The circum-œsophageal ring (*d. o. nv. r.*) is of irregular thickness, and is not always readily traceable throughout a series of sagittal sections of the disc. Of the nerve cords which radiate from the ring Cuénot has described five principal pairs, which are said to run one on either side of the five ambulacral grooves of the tegmen calycis and from thence traverse the arms in the same relative position. The present writer has found the tracing of these nerves a matter of very considerable difficulty. In individual

sections of the arms in which a nerve appears in the position indicated by Cuénot it may be seen to give off twigs to the ambulacral tentacles and to others which run towards the dorsal face of the arm (Pl. III., fig. 29, *lt. nv. c.*) where they are said to unite with similar twigs from the brachial cords of the apical system. Moreover, it has not been shown how the single pair of nerve cords which are said to run alongside the ambulacral grooves of the tegmen calycis divide at the point of origin of each pair of arms, so as to furnish a lateral nerve cord to their inner faces. Nerves from the circum-œsophageal ring are traceable to the oral tentacles (Pl. V., fig. 52), and two cords traverse the anal interradius to innervate the anal funnel. Similar nerves occur in the other interradii, and their branches appear to anastomose, thus forming a sub-tegumentary plexus. From the latter, nerve twigs go to innervate the bands and trabeculæ of connective tissue in the body cavity. It is highly probable that this sub-epithelial system is in continuity with the superficial system as well as with the apical system.

The Apical system consists of a cup-shaped structure, the central capsule, from which stout nerve cords proceed and eventually unite in pairs to form the apical or dorsal nerve cords of the arms (Pl. V., figs. 48, 49, and 52; Pl. VI., figs. 54, 55, 56, 57, and 59, *cen. cap.*). The central capsule is lodged in the concavity of the centro-dorsal plate, to the walls of which it is closely applied, and its oral or ventral face is covered by the rosette plate (Pl. VI., fig. 59). Its thick walls form a close investment around the chambered organ; and, as has been already stated above, the cirrus vessels which radiate from the chambers are also invested by tubular extensions of the capsule which form the so-called cirrus cords (figs. 52 and 59).

From the margin of the oral face of the capsule arise five interradially situated and diverging pairs of cord-like extensions of the capsule (Pl. V., figs. 48 and 49). Trending towards the oral face of the disc, and entering the substance of the radial plates through the apertures seen in fig. 4, Pl. I., these cords unite to form five radial nerves, the left cord of one interradial pair uniting with the right one of the pair next to it. Just beyond the points of junction of the cords the five radial nerves are connected together by a pentagonal commissure (Pl. V., figs. 48 and 49; Pl. VI., fig. 56, *pnt. com.*) lodged in a canal of corresponding shape which traverses the five radials, in the lateral faces of which its openings may be seen (Pl. I., fig. 6). Beyond the commissure the radial nerve cords pass out of the radial plates into the axial canals of the first primibrachials, and from thence into the second primibrachials or axillaries. On entering the latter each nerve divides into right and left branches (Pl. VI., fig. 53), which pass outwards through the corresponding oblique facets of the plate to form the axial cords of the arms. The two branches are connected together just beyond their point of origin, and while still within the axillary plate, by a transverse commissure (*tr. com.*) and a chiasma (*chi.*), the latter occupying the triangular space bounded by the former and the diverging cords. Passing outwards from the Axillary plate, each branch enters the arm of its own side to become the brachial nerve cord of the apical system (*br. nv. c.*). Traversing the whole length of the arm through the axial canal which perforates all the calcareous joints, the cord gives off alternately right and left branches to the pinnules, and these arise from double roots (Pl. VI., fig. 60, *d. r. pn. br.*). Further, the cord gives off in each joint two pairs of nerves (Pl. III., fig. 29) which are considered to be

principally sensory. One pair arise from the oro-lateral (ventral) border of the cord (*vn. nv.*), and furnish principal branches to the interarticular muscles, numerous twigs which end in sensory cells of the external epithelium, and branches which are said to unite with similar ones from the lateral brachial cords of the deeper oral system. The other pair arise from the dorso-lateral border of the cord (*dr. nv.*), and the numerous branches divide again and again until, as exceedingly fine twigs, they end like some of those of the oral pair, in continuity with the sensory cells of the external epithelium. In longitudinal sections of the arms (Pl. V., fig. 50) the brachial nerve cord (*br. nv. c.*) presents a sort of nodal enlargement between every two joints, those between which a syzygy occurs excepted. These are the points of origin of nerves which are distributed to the interbrachial muscles and ligaments, and which are exceedingly difficult to trace.

In histological structure the central capsule and its radial cords are practically uniform. They consist of extremely delicate fibrils, with numbers of very minute ganglion cells intercalated between them. In the more apical portion of the central capsule the fibrils have no definite arrangement, but in the walls of its oral aspect they are disposed for the most part concentrically around the chambered organ (fig. 55). In the radial cords the nerve fibrils do not form one homogeneous bundle, but are bound together to form strands which are definite in position and direction. Thus, the chiasma (Pl. VI., fig. 53, *chi.*) is formed by two strands which run along the outer lateral borders of the undivided cord, and from thence cross over, one under the other, to be merged into similar strands which run along the inner borders of the two branches and, by the union of their proximal ends, form

the commissure. Transverse sections of the brachial nerve cords (Pl. III., fig. 39) show that their fibrils form five definite strands. Two of these run along the oral aspect of the cord and are in contact in the middle line; while the remaining three traverse its dorsal face, one being median and the other two lateral. Both the lateral strands contribute fibrils to the pinnular branches. The organic reticulum which forms the bases of the skeletal parts is a definite investing layer around the capsule and the cords.

Very little is known of the functions of the superficial oral and deeper oral nervous systems. The sub-epithelial bands which underlie the ambulacral grooves so closely resemble, in histological structure and relation to the ambulacral epithelium, the sub-epithelial bands of the Asteroidea, which are undoubtedly nerves, that there can be little doubt of their nervous character; but the experiments of Carpenter (**6**), Milnes Marshall (**7**), and Jickeli (**8**) show that neither the superficial oral nor the deeper oral system plays more than a very subordinate part in sensation and movement. In all probability the former is concerned with the ambulacral epithelium and the highly sensitive tentacles bordering the ambulacral grooves, structures with which the system is in close anatomical relation. The experiments cited above show that the apical system is the principal one. That the central capsule is a centre from which the complex co-ordinated movements of swimming and righting are controlled is shown by the fact that when this organ is entirely removed the movements cease; on the other hand, evisceration, with consequent removal of the circum-oral ring of the ambulacral system, has no effect whatever upon them. The commissure lodged in the pentagonal canal of the radial plates co-ordinates the movements of

the whole number of arms, as is shown by the partial or complete failure of co-ordination when the commissure is injured or wholly destroyed; while the commissure and chiasma which connect the bifurcating nerve cords in the second primibrachial in like manner co-ordinate the movements of each pair. The brachial cords are the paths along which afferent and efferent impulses travel to and from the central capsule. If the cord only be severed at any one point of an arm, leaving the ambulacral nerve band intact, even the severest irritation applied to the distal portion of the arm beyond the injury fails to excite any response in the disc and the remaining uninjured arms. Irritation applied to the cut end of the cord in the proximal part of the arm causes immediate and strong flexion of that and all the uninjured arms, while irritation applied to the cord in the distal part of the arm causes similar movements in that part of the arm alone.

The Genital Organs.

The genital organs, testes and ovaries, are specialised portions of a system of sterile cords which radiate from the disc and traverse the arms and pinnules. In a transverse section of an arm (Pl. IV., fig. 41) there may be seen in the horizontal partition which divides the cœliac from the subtentacular canals another rounded cœlomic space, lined like its neighbours with endothelium (*gen. lc.*). This is the genital lacuna or sinus. It encloses another tube, the genital strand or rachis (*gen. ra.*), which is suspended to its walls by slender filaments of connective tissue. At first a solid cord, the rachis eventually becomes a hollow tube lined with germinal epithelium. In its course along the arm it supplies a branch to each pinnule with the exception of the first. In the pinnules

the branches widen out enormously to form ovate cavities, the gonads (Pl. VI., fig. 61, *tes.*; fig. 62, *ov.*), which equal in length five or six of the pinnular joints, and, at the period of sexual maturity, are filled with spermatozoa, or ova, derived from the germinal epithelium.

The testes are invested by a delicate layer of connective tissue in which there are oblique muscular fibres; on the inner side this layer is thrown into many projecting folds, which greatly augment the surface upon which the spermatoblasts are developed. The mature spermatozoon has a conical head and a middle piece to which the tail is attached. Many of the germinal cells which line the ovaries remain small and form a follicular investment around the developing ova (fig. 62, *fol. c.*).

The course of the genital sinuses and the included genital strands in the disc is very difficult to trace. The sinuses almost certainly open into the circum-œsophageal plexus, but, in the adult animal at least, the genital rachids are not traceable into continuity with the oral end of the axial organ, from which they are said to arise in the larva. A sexually mature Antedon may be easily recognised by its swollen pinnules, to which the extruded ova, which are fertilised externally, adhere in little groups for four or five days, and until the embryo within has developed the rudiments of its skeleton. The gonads of the more proximal pinnules appear to be the first to ripen. The eggs probably escape from the ovaries by rupture of their walls at one or more points of least resistance, while the spermatozoa are discharged through a small funnel-like projection upon one or both sides of the gonad (fig. 61). Sexual maturity occurs in the months of May and June around the Isle of Man, but the time differs a little according to geographical position. According to Cuénot, it occurs in March and April in the

Mediterranean, and from the end of May to the end of June at Trieste.

Segmentation of the egg results in the formation of a spherical embryo, which consists of a single layer of cells enclosing a cavity filled with gelatinous matter. This is a cœloblastula. Immediately after the completion of this initial stage, a depression, due to invagination of the wall of the cœloblastula, appears at one pole, and the invaginating portion soon becomes bilaminar. The slit-like aperture of the invagination is the blastopore. The embryo is now a gastrula. The cells of the inner layer of the invagination migrate into the gelatinous matter to form mesenchyme (Pl. VI., fig. 63, *mes.*). The external surface of the embryo is covered with cilia, the action of which causes it to rotate within the egg membrane. Presently the blastopore closes completely, and the archenteron becomes a closed vesicle. A circular furrow now appears in its walls and, gradually deepening, eventually separates the archenteric cavity into two distinct vesicles, of which the anterior is slightly the larger (fig. 63). The latter gives rise to the intestine and the hydrocœl, while from the posterior vesicle the cœlom and the chambered organ are derived. The posterior vesicle elongates transversely; and concurrently, the anterior one is produced into horn-like dorsal and ventral extensions (fig. 64, *me. hy. vs.*), which grow around it until they touch, but do not communicate. The two ends of the posterior vesicle now enlarge, while the median portion, encircled by the horns of the anterior vesicle, becomes more tubular. The embryo is now bilaterally symmetrical, and begins to assume an oval form. A ventral outgrowth from the anterior vesicle now forms the rudiment of the hydrocœl (*ru. hy.*), and the vesicle itself becomes the intestine. The enlarged ends of

the posterior vesicle continue to increase in size, and by the eventual disappearance of the median connecting portion, become right and left enterocœlic sacs. About the fourth day the embryo assumes a still more elongated form, and at its anterior end a tuft of long cilia appears. This is borne by a thickened and slightly depressed area of the ectoderm known as the neural plate, in the deeper layers of which the rudiments of the larval nervous system appear. Close behind the neural plate, on the antero-ventral face of the embryo, is a slight depression, the adhesive pit, by means of which the free swimming larva eventually attaches itself. The right enterocœlic sac invades the segmentation cavity and spreads dorsally forwards and over the intestine. The left sac enlarges in the opposite direction and surrounds the posterior border of the intestine. The rudiment of the hydrocœl is now separated from the intestine, but remains for a short time in open communication with a small outgrowth from its anterior wall, the parietal sinus. The intestine undergoes changes of shape and becomes a vesicle. The rudiments of the skeletal system now make their appearance in the form of five oral plates, five basals, from three to five infrabasals, and about eleven segments of the stalk (fig. 65, *jt. sk.*). Externally the embryo is encircled by five ciliated bands (*cl. r.*), and there is a depression in the ventral ectoderm, known as the vestibule (*vs.*), the significance of which will appear later. At this stage the embryo is hatched out and becomes a free-swimming larva, with the tuft of long cilia directed forwards. Between the third and fourth ciliated rings there is a minute aperture, the primary water pore. During the free swimming stage the larval nervous system attains its highest development, and the adhesive pit enlarges and becomes glandular. The vestibule becomes tubular, owing

to the fusion of its lateral edges in the median line, a small anterior aperture being retained. The intestine assumes the form of a hollow plate, and the hydrocœl lies in its ventrally directed cavity (fig. 65). The rudiments of the chambered organ now appear as five tubular outgrowths from the right enterocœl vesicle; and the skeletal joints of the stalk, which are at first horse-shoe shaped, surround them. The hydrocœl vesicle separates from the parietal sinus and assumes a horse-shoe shape. Five outgrowths of its wall appear, each of which eventually gives rise to three primary tentacles, while the primary water tube (stone canal) appears at the blind end of the left limb of the vesicle. The parietal sinus takes up a new position in front of the hydrocœl and finally communicates with the exterior through the hydropore. Soon after the larva attaches itself the ciliated rings and tuft and the neural plate disappear. The vestibular aperture disappears and the vestibule itself takes up a new position at the posterior end of the larva, and by the assumption of a pentagonal form, determines the radiate structure of the adult. It is accompanied in its movements by the hydrocœl, so that the two structures maintain their relative positions. Communication between the hydrocœl vesicle and the parietal sinus is re-established by the water tube, which breaks through into the former. Concurrently with these changes a store of nutritive material is accumulated within the intestinal vesicle by numerous cells which become detached from its wall and finally completely fill it. A funnel-like depression of the floor of the vestibule passes through the hydrocœl ring and forms the œsophagus. A corresponding process of the intestinal vesicle eventually fuses with it. The left cœlomic sac becomes the oral cœlom, and the right sac the aboral or apical cœlom.

The axial organ arises as an epithelial thickening upon one of the primary mesenteries—the longitudinal accessory—formed by the approximation of the cœlomic sacs. Concurrently with the shifting of the vestibule to the posterior end of the larva a re-arrangement of the skeletal plates takes place.

The five orals (Pl. VII., fig. 66, *or. p.*) form a pyramid on the roof of the vestibule, while the five basals (*bas. p.*) form a similar but inverted pyramid in the body wall of the calyx. The plates forming both pyramids are interradial in position. Around the uppermost joints of the stalk there are from three to five small infrabasals, which are said to eventually fuse with the centro-dorsal. During subsequent development of the larva the definitive mouth is formed by perforation of the vestibule, and radial grooves soon divide the vestibular roof into five interradial valves, in each of which lies an oral plate. Between these the five groups of primary tentacles and five primary sacculi make their appearance (fig. 66). The superficial oral nervous system appears as a multilaminar ring of ectoderm, the deeper cells of which give rise to the nerve tissue. The anus, in the formation of which the ectoderm takes no part, breaks through in the posterior interradius, in which also the primary ciliated funnel (hydropore) appears (fig. 68, *hyp.*) The chambered organ is now shut off from the aboral cœlom, and the axial organ becomes an independent strand of cells, at first solid, but subsequently hollow. The horse-shoe-shaped hydrocœl (fig. 68, *hyd. r.*) becomes completely closed and forms the circum-oral water vessel. Four new ciliated funnels and four water tubes (stone canals) make their appearance, so that there is one of each in all five interradii. The larva now consists of a well-marked stalk, composed of from eight to ten cylindrical joints, and a more or less expanded

calyx, supported, as we have already seen, by the circlets of basal and oral plates. The lowest joint of the stem (figs. 66, 67, and 69) assumes a discoid or lobate form, so as to afford firm attachment to the substratum upon which the larva has fixed itself, whilst the highest is also somewhat expanded as a support for the calyx. In the latter the basal and oral plates are now fully developed.

As will be seen in fig. 66, the oral plates usually stand almost erect, thus exposing the underlying oral apparatus, but they can be closed down upon it. Five pairs of tentacles make their appearance between the groups of three primary ones (fig. 68, *se. ten.*), making twenty-five in all; and whereas at first the five tentacles in each radius are connected by a common tentacle canal arising from the circum-oral water vessel, they eventually arise separately from the latter. Another circlet of plates, the radials, now make their appearance in the spaces left between the contiguous angles of the basal and oral plates (fig. 67, 69, and 70, *rd.*). As their name implies, they are radial in position. A small asymmetrical plate, the anal, also appears between two of the radials, and on a level with them, but this undergoes resorption at a later period. The next plates to appear are the first primibrachials, which, supported by the radials, project upwards and slightly outwards between the orals (fig. 67, *pmb.* 1). These are soon followed by the second primibrachials or axillaries (*pmb.* 2), upon the distal extremities of which the first pair of secundibrachials (*sec.* 1) appear in due course. Eventually the basal plates fuse to form the rosette, which covers in the chambered organ and central capsule. By the outward growth of the arms and the consequent enlargement of the circumference of the tegmen calycis, the oral plates are left upon the oral

surface, and at a later period undergo resorption. When fully developed the larval stalk consists of about twenty joints, of which the two or three uppermost are short and disc-like (fig. 69). The first whorl of cirri, numbering five, is developed, interradially, upon the under surface of the uppermost joint, which ultimately fuses with the centro-dorsal. The members of the next formed whorl alternate in position with the first, and to these a third whorl is generally added before the young Antedon detaches itself from its stalk and becomes free. The first pinnules are formed before the larva detaches itself from its stalk, and when each of the arms consists of about twelve secundibrachial joints. A bifurcation now presents itself at the growing extremity of the arm, one ramus of which grows more rapidly than the other, and in a line continuous with that of the axis of the arm. The shorter ramus diverges at an acute angle and becomes the primary pinnule. With the exception of the second secundibrachial, upon which an oral pinnule early appears, the first formed and more proximal joints of the arm do not bear pinnules until the larva become free.

The larva is capable of considerable movement. Its stalk can be bent from side to side or thrown into a short spiral, while the arms are repeatedly extended and flexed with considerable vivacity. Detachment of the young Antedon from its stalk is not an accidental circumstance, resulting merely from atrophy of the upper joints of the latter. It is preceded by the appearance, at a point immediately below the centro-dorsal plate, of a narrow band of fine fibrils which run parallel to the axis of the stalk, and unite two layers of very minute cells. The plane of rupture passes between these two layers. Detachment does not take place until the cirri are sufficiently developed to enable the animal to attach itself

to surrounding objects, such as *Laminaria*, *Delesseria*, Hydroids and Polyzoa.

Regeneration.

Antedon has long been known to possess considerable power of regeneration. The visceral mass may often be detached with great ease, and, as shown by Dendy (**9**), may be completely regenerated in the course of a few weeks. Specimens are occasionally found (**10**) only partially eviscerated, and the original visceral mass remains, more or less displaced, but with a new one developed in the normal position. Przibram (**11**) found that the visceral mass could be transplanted with success from one individual to another. Regeneration and transplantation cannot occur, however, in the absence of the apical nervous system. Regeneration of the arms is of very frequent occurrence, and not uncommonly results in monstrosity. Perrier (**12**) has fully discussed regeneration of the arms.

Parasites.

Antedon bifida is the host of a number of parasites and commensals, of which the best known are two species of Myzostomidæ, *Myzostoma glabrum* and *M. cirriferum*. The former is found fixed in the neighbourhood of the mouth in specimens from the Mediterranean and the Adriatic, and the latter occurs in large numbers on the disc and arms of specimens from the same localities as well as from various parts of the British coasts, including the Isle of Man. A small Gastropod, *Stylina comatulicola*, is not uncommonly found attached by means of its proboscis to the anal funnel or to the cirri of specimens from the Mediterranean. Several Copepoda, including *Collocheres gracilicauda*, Brady, have been found attached to

the surface of the disc of specimens from various localities, and other Crustacean parasites have been found sunk in the tissues or inhabiting the alimentary canal. A pear-shaped holotrichous Infusorian is frequently abundant in the alimentary canal of specimens collected off the Isle of Man and in the neighbourhood of Roscoff, and a peritrichous form, *Hemispeiropsis antedonis* infests the surface of the body of Mediterranean specimens.

Methods.

Antedon may be killed rapidly and with the arms fully extended by immersion in fresh water. Corrosive-acetic mixture is a good fixative, but the writer's best results were obtained by the use of corrosive-acetic mixture 3 vols. and 10 per cent. solution of formalin 1 vol. For sectioning, specimens which have died with the arms fully extended laterally should be selected, so that the primibrachials and proximal secundibrachials may be as nearly as possible in the same plane as the radials. After fixation, the specimens should be well washed in several changes of 70 per cent. alcohol. Decalcification may be effected by the addition of 3 per cent. of strong nitric acid to 97 c.c. of 70 per cent. alcohol; and the specimens, especially if large, should remain in this for at least twenty-four hours after bubbles of gas have ceased to escape from them. All trace of the nitric acid should then be removed by liberal washing in 70 per cent. to 90 per cent. alcohol. For staining sections the writer has used Heidenhain's iron hæm-alum method with excellent results, and methyl-blue-eosin is also good.

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DESCRIPTION OF THE PLATES.

List of Reference Letters.

amb. ep. = Ambulacral epithelium.
amb. gr. = Ambulacral groove.
amb. nv. = Ambulacral nerve.
an. = Anus.
an. fl. = Anal funnel.
arc. = Archenteron.
ax. cn. = Axial canal.
ax. or. = Axial organ.
ax. si. = Axial sinus.
bas. = Basal plate.
bl. lc. = Blood lacuna.
br. nv. c. = Brachial nerve cord.
cal. cl. = Caliciform cell.
cen. cap. = Central capsule.
chi. = Chiasma of radial cords.
ch. or. = Chambered organ.
ci. = Cirrus.
ci. cd. = Cirrus cord.
cil. pt. = Ciliated pit.
ci. v. = Cirrus vessel.
cl. fn. = Ciliated funnels.
cl. r. = Ciliated ring.
cnt. dr. = Centro-dorsal plate.
cn. ts. = Connective tissue.
c. o. bl. r. = Circum-oral blood vessel.
cœ. ca. = Cœliac canal.
cœ. en. = Cœlomic endothelium.
cog. = Coagulum.
c. o. nv. r. = Circum-oral superficial nerve ring.
c. o. w. v. = Circum-oral water vessel.
ct. = Cuticle.
cv. p. = Covering plate.
d. o. nv. = Nerves of deeper oral system.
d. o. nv. r. = Circum-œsophageal deeper nerve ring.
dr. nv. = Dorsal nerves from brachial cord.
d. r. pn. br. = Double root of pinnular branch of brachial cord.
ect. = Ectoderm.
ep. = Epithelium.
ex. ch. or. = Extension of chambered organ.
ex. lig. = Extensor ligaments.
flx. m. = Flexor muscles.
gen. bl. lc. = Genital blood lacuna.
gen. ra. = Genital rachis.
hyd. = Hydrocœl.
hyd. r. = Hydrocœl ring.
hyp. = Hydropore.
i. m. f. = Isolated muscular fibres.
int. = Intestine.
int. ep. = Intestinal epithelium.
int. lig. = Interarticular ligaments.
jt. pn. = Calcareous joint of pinnule.
jt. sk. = Calcareous stalk joint.
l. cœ. = Left cœlom.
l. m. f. = Longitudinal muscular fibres.
lt. nv. c. = Lateral cord of deeper oral nervous system.
me. hy. vs. = Mesentero-hydrocœl vesicle.
mes. = Mesenchyme.
mth. = Mouth.
nv. l. = Nerve layer.
or. = Oral plate.
or. pn. = Oral pinnule.

or. tn. = Oral tentacle.
ov. = Ova.
ovr. = Ovary.
pd. = Pedal plate.
pmb. 1. = First primibrachial.
pmb. 2. = Second primibrachial.
pn. = Pinnule.
pnt. com. = Pentagonal commissure.
pr. ten. = Primary tentacles.
r. cœ. = Right cœlom.
rad. nv. = Radial cords of apical nervous system.
rd. = Radial plate.
ros. = Rosette plate.
ru. hy. = Rudiment of hydrocœl.
r. w. v. = Radial water vessel.
sac. = Sacculus.
sb. e. nv. f. = Sub-epithelial nerve fibres.
sec. 1. = First secundibrachial.
s. te. ca. = Sub-tentacular canal.
se. ten. = Secondary tentacle.
sn. pp. = Sensory papilla.
s. n. s. = Sub-neural sinus.
sph. fb. = Fibres of sphincter muscle in transverse section.
sp. or. = Spongy organ.
st. = Stomach of larva.
syz. = Syzygy.
ten. = Tentacle.
tes. = Testis.
tg. cl. = Tegmen calycis.
tn. vs. = Tentacular vessel.
tr. com. = Transverse commissure of radial cords.
v. f. = Valvular fold.
vn. nv. = Ventral nerves from brachial cord.
w. t. = Water tube.

Plate I.

Fig. 1. *Antedon bifida*, showing the attitude assumed by the animal when at rest. Natural size.

Fig. 2. *Antedon bifida*, showing the disposition of the arms in swimming. Natural size.

Fig. 3. *Antedon bifida*, viewed from the aboral surface. The cirri were removed from two-thirds of the periphery of the centro-dorsal to show the bases of the arms. × 5.

Fig. 4. A radial plate, viewed from the axial face. × 8.

Fig. 5. Abaxial (outer) face of a radial plate. × 8.

Fig. 6. Lateral face of a radial plate. × 8.

Fig. 7. Oral face of a radial plate. × 8.

Fig. 8. Axial face of a first primibrachial. × 8.

Fig. 9. Abaxial face of a first primibrachial. × 8.

Fig. 10. Lateral face of a second primibrachial axillary. × 8.

Fig. 11. Oral face of a second primibrachial. × 8.

Fig. 12. Proximal face of a first secundibrachial. × 8.

Fig. 13. Proximal face of a secundibrachial joint from the base of an arm. × 8.

Fig. 14. Distal face of a secundibrachial joint from the base of an arm. × 8.

Fig. 15. Distal face of a secundibrachial joint from near the tip of an arm. × 8.

Fig. 16. Distal face of the hypozygal joint of the first syzygial pair. × 8.

Fig. 17. Rosette plate, from the oral surface. × 12.

Fig. 18. Lateral view of rosette plate. × 12.

Fig. 19. Oral face of centro-dorsal plate showing its cavity. × 10.

Fig. 20. Half of aboral face of centro-dorsal plate, showing the sockets for the articulation of the cirri. × 10.

Fig. 21. Side view of four secundibrachial joints from the base of an arm, with the proximal joints of two pinnules in situ. The soft parts had been removed by maceration in caustic potash solution. × 6.

Plate II.

Fig. 22. Portion of a vertical section of the tegmen calycis, showing two ciliated funnels. × 320.

Fig. 23. Oral face of the disc, with the alimentary canal, reconstructed from serial sections, seen by transparency. × 6. Adapted from L. Cuénot.

Fig. 24. Oral face of the disc and the bases of the arms of *Antedon bifida*. × 6.

Fig. 25. Longitudinal section of the lower portion of the œsophagus. × 320.

Fig. 26. Section of the ectoderm of the dorsal face of an arm. × 400.

Fig. 27 Portion of a longitudinal section of the anal funnel. × 320.

Fig. 28. The central portion of fig. 24. × 12.

Plate III.

Fig. 29. Transverse section of an arm. × 40.

Fig. 30. A pinnular tentacle, in optical section. × 300.

Fig. 31. Transverse section of pinnular tentacle. × 300.

Fig. 32. An oral pinnule. × 12.

Fig. 33. An ordinary pinnule, with ovary containing nearly ripe eggs. × 25.

Fig. 34. Distal end of a pinnule from the distal end of an arm. × 177.

Fig. 35. Fibres of extensor ligaments. × 400.

Fig. 36. Fibres of flexor muscle. × 400.

Fig. 37. Portion of longitudinal section of a pinnule, showing three ciliated pits. × 320.

Fig. 38. A cirrus. × 14.

Fig. 39. Transverse section of brachial nerve cord. × 180.

Fig. 40. *a* & *b*. Vertical sections of two sacculi, showing stages in the formation of the masses of granules. × 320.

Plate IV.

Fig. 41. Ventral portion of a transverse section of an arm. × 110.

Fig. 42. Transverse section of ambulacral epithelium and the sub-epithelial nerve band. × 650.

Fig. 43. Longitudinal section of ambulacral epithelium and the sub-epithelial nerve band. × 650.

Fig. 44. Portions of two transverse sections of the axial organ. × 320.

Fig. 45. Transverse sections of a group of tubular blood lacunæ. × 180.

Fig. 46. Transverse section of the axial organ. × 180.

Fig. 47. Portion of a sagittal section of the disc, passing through the anal interradius. × 180.

Plate V.

Fig. 48. Side view of central capsule and pentagonal commissure of the apical nervous system, reconstructed from serial sections. × 20.

Fig. 49. Aboral view of central capsule and pentagonal commissure of the apical nervous system, reconstructed from serial sections. × 20. The cirrus cords are not represented in this figure.

Fig. 50. Sagittal section of an arm. × 40. The structures on the ventral side of the cœliac canal are not represented.

Fig. 51. The "spongy organ," as seen in a horizontal section of the disc. × 122.

Fig. 52. Diagram of a sagittal section of the disc, partly after Ludwig.

Plate VI.

Fig. 53. Horizontal section of a radial nerve cord at the point of bifurcation to form the brachial cords, showing the commissure and chiasma. × 55.

Fig. 54. Horizontal section of the central capsule and the chambered organ, at about the level of the line * in fig. 59. × 40.

Fig. 55. Horizontal section of the central capsule and the chambered organ, at about the level of the line * * * in fig. 59. × 40.

Fig. 56. Horizontal section of the pentagonal commissure, at about the level of the line † in fig. 59. × 40.

Fig. 57. Horizontal section of the central capsule and the chambered organ, at about the level of the line * * in fig. 59. × 40.

Fig. 58. Transverse (*a*) and longitudinal (*b*) sections of a cirrus cord and the included cirrus vessel. × 350.

Fig. 59. Portion of a sagittal section of the disc, showing the central capsule, radial and cirrus cords, chambered organ and axial organ. × 40.

Fig. 60. Horizontal section of the base of an arm passing through the first four secundibrachials, and showing the double roots of the two first pinnular branches of brachial nerve cord. × 30.

Plate VII.

Fig. 61. Horizontal longitudinal section of a pinnule, with a ripe testis showing the lateral papilliform projection through which the spermatozoa would eventually escape. × 56.

Fig. 62. Transverse section of a pinnule, with a nearly ripe ovary. × 40.

Fig. 63. Horizontal longitudinal section of an embryo, fifty-seven hours old. After Seeliger, from Lang.

Fig. 64. Posterior end of an embryo, sixty hours old, seen from the right side. After Seeliger, from Lang.

Fig. 65. Free-swimming larva, from the right side. × 177.

Fig. 66. A young attached larva, showing the basal and oral plates, the primary tentacles and the primary sacculi. × 40.

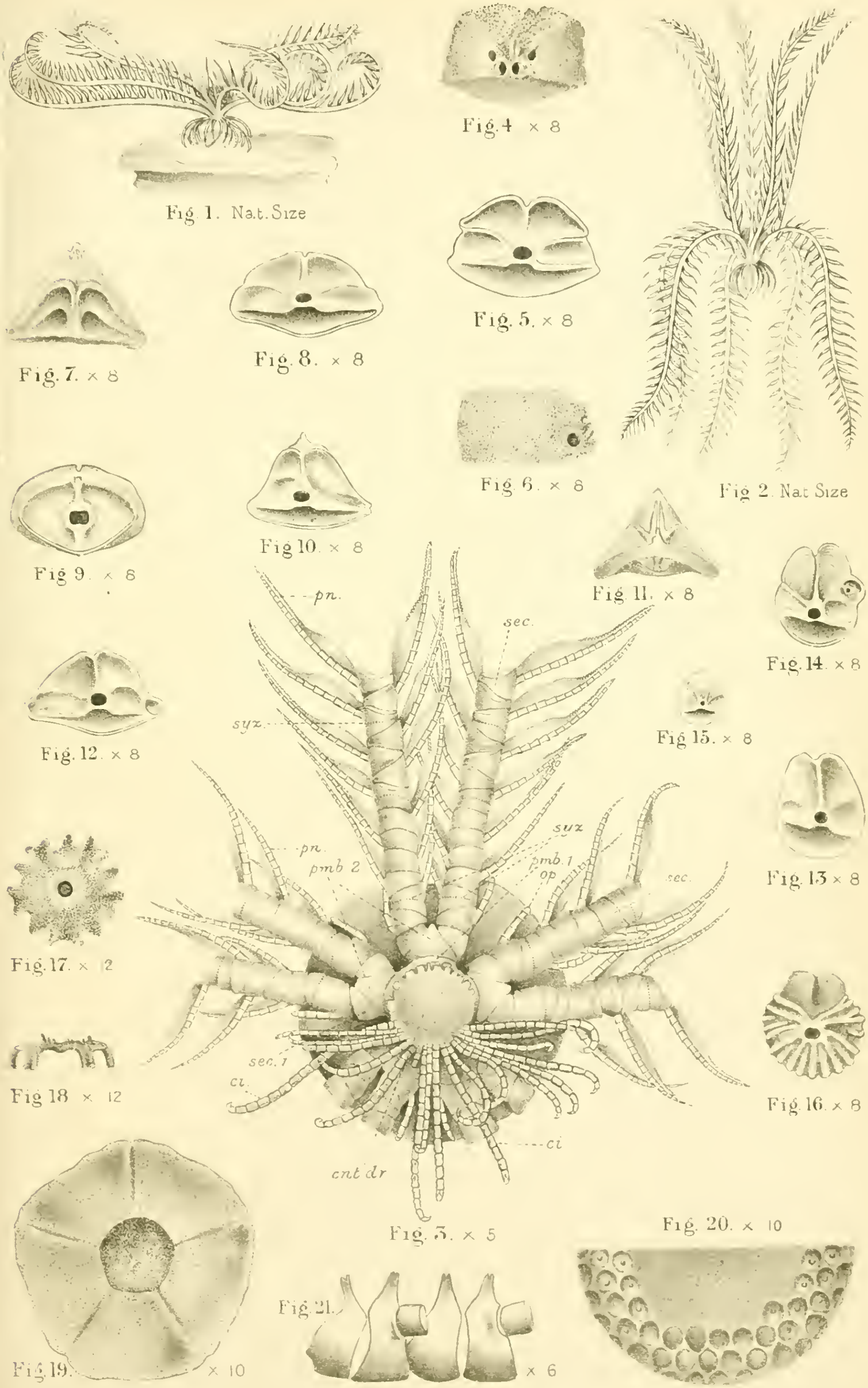
Fig. 67. An older attached larva, showing the radial plates interposed between the basals and orals, and supporting the two primibrachials in each of the radii. × 40.

Fig. 68. The calyx of a decalcified attached larva, five weeks old, viewed from the left side. After Seeliger, from Lang.

Fig. 69. A still older attached larva, showing the five pairs of arms as they appear before the development of the first pinnules. × 22.

Fig. 70. The calyx and part of the stalk of a nearly fully developed attached larva, showing the developing cirri. × 12.

Fig. 71. Portion of one of the arms of the specimen represented in fig. 70, showing the "covering" plates.



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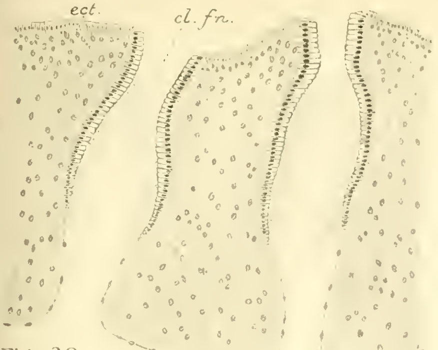

Fig. 22. × 320

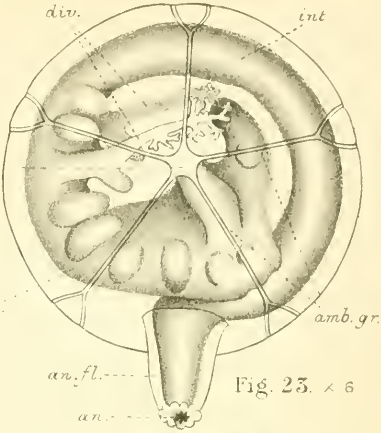

Fig. 23. × 6

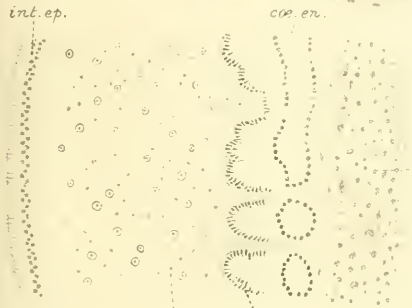

Fig. 27. × 320

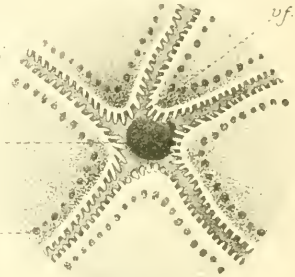

Fig. 28. × 12

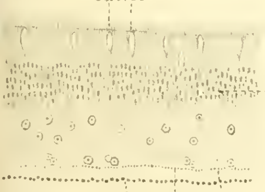

Fig. 25. × 320

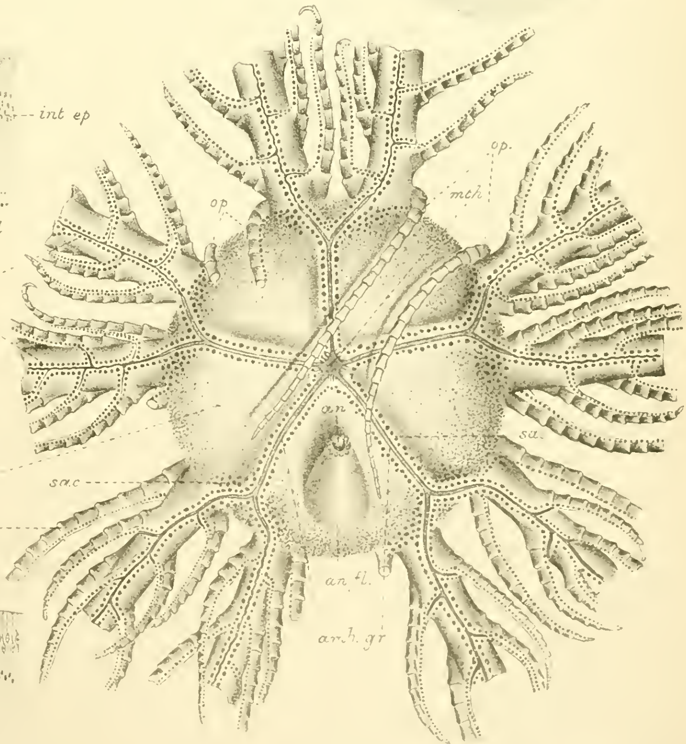

Fig. 24. × 6

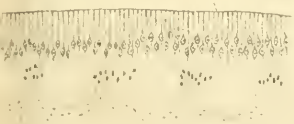

Fig. 26. × 400

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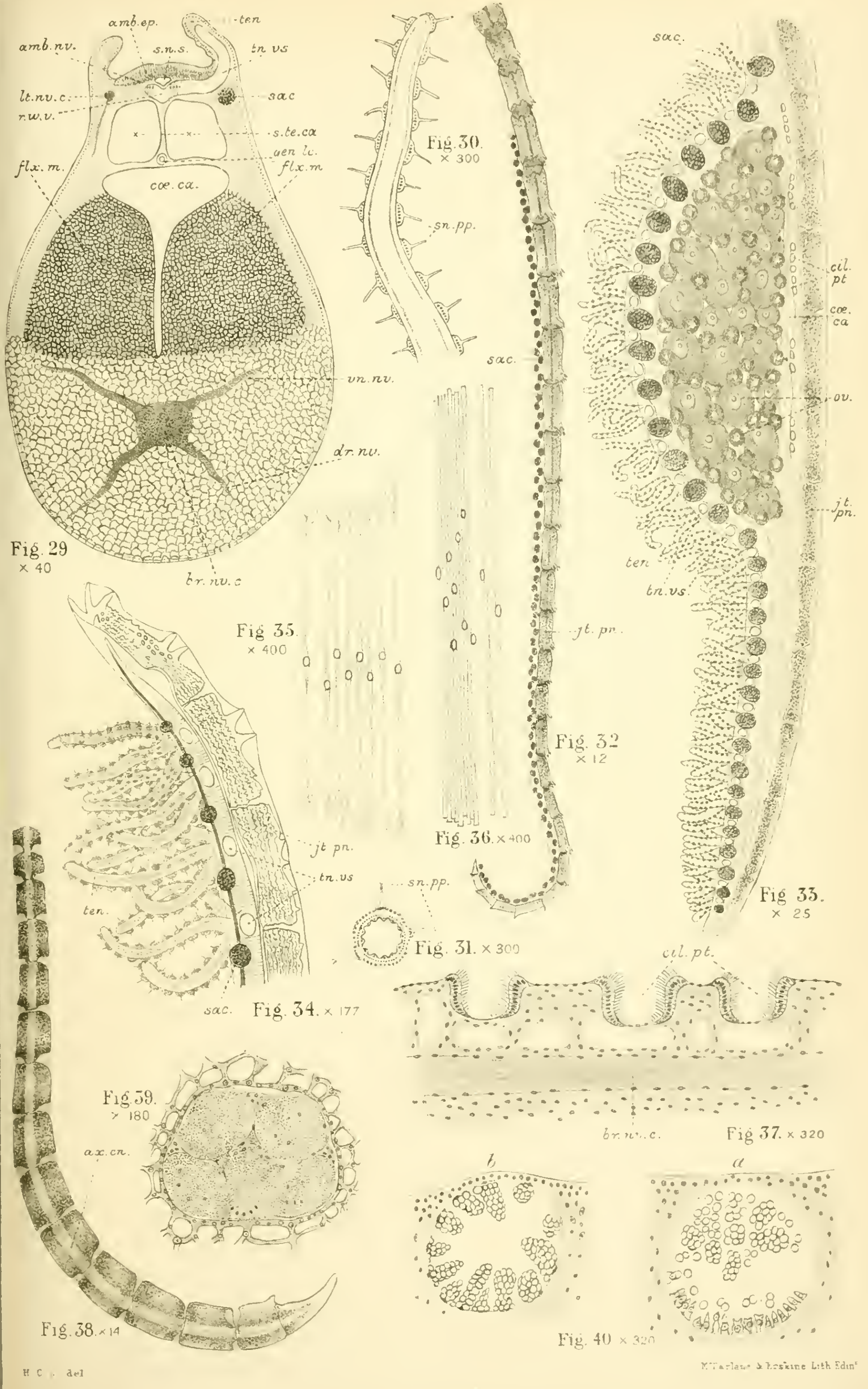

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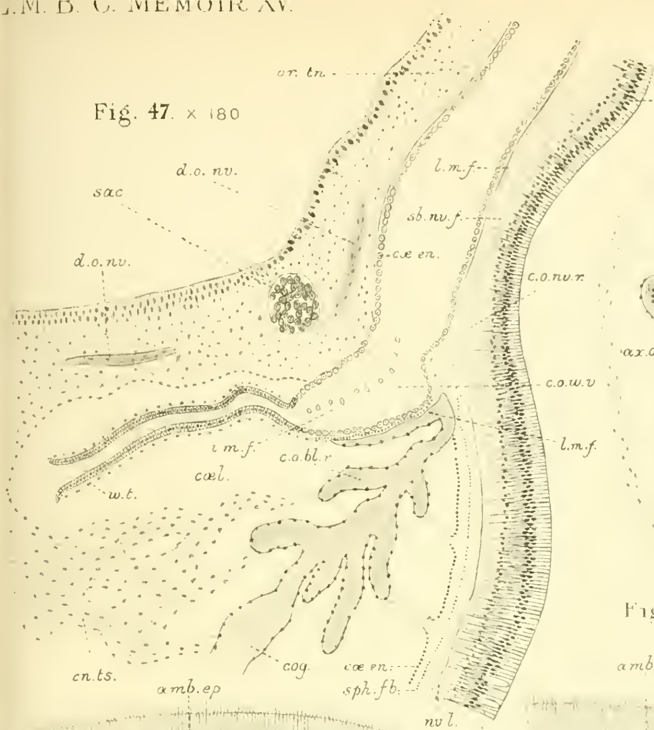


Fig. 47. × 180

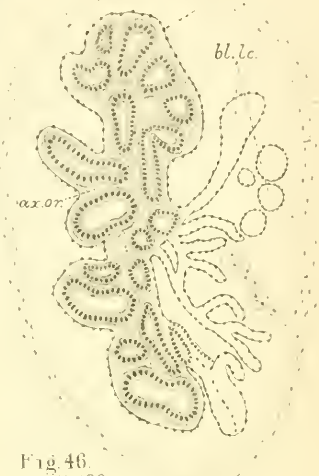
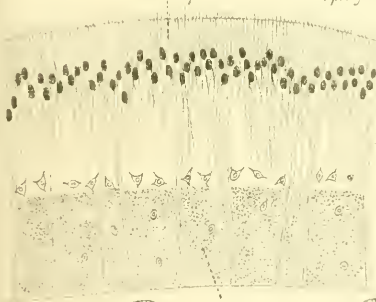


Fig. 46. × 180



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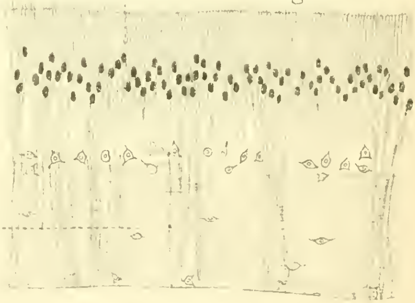

Fig. 43. × 650

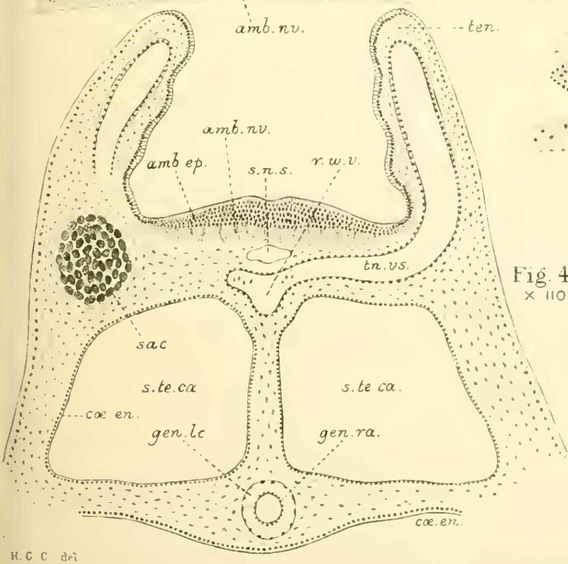

Fig. 41. × 110

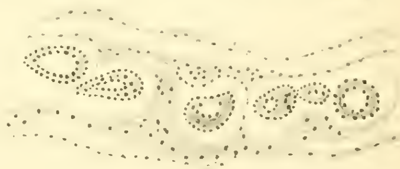
Fig. 45. × 180

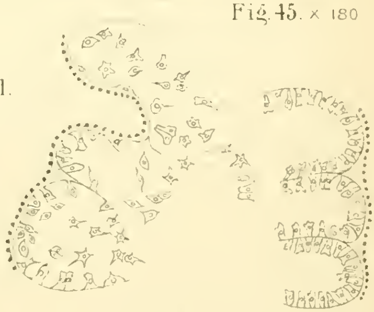
Fig. 44. × 320

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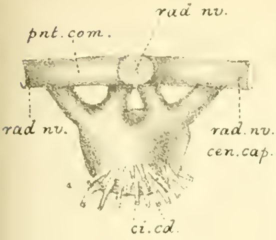


Fig. 48. × 20

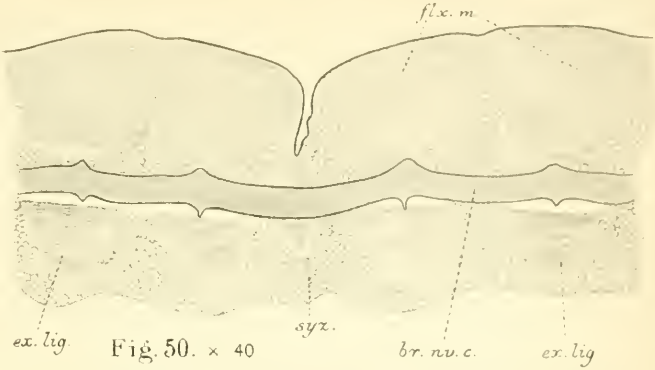


Fig. 50. × 40

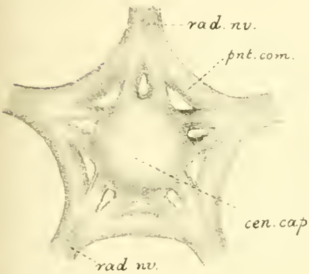


Fig. 49. × 20

Fig. 51. × 122

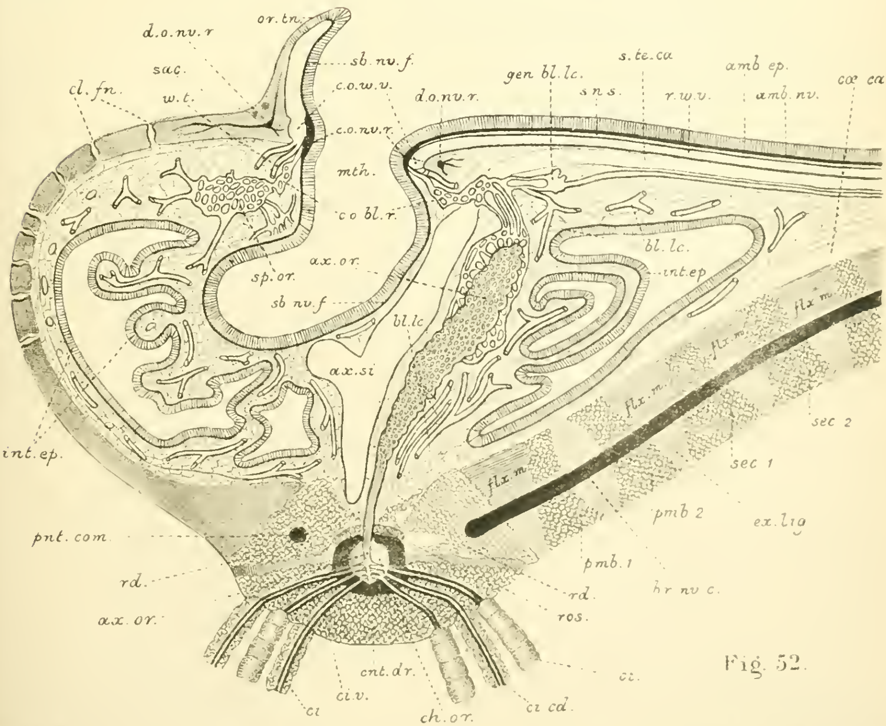


Fig. 52.

Fig. 54. × 40

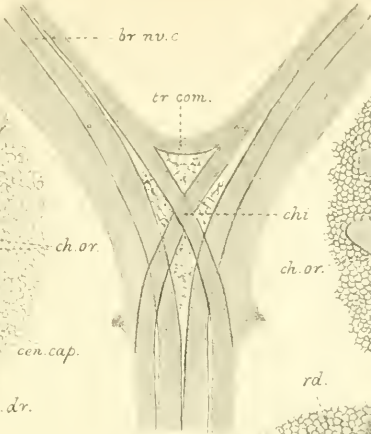


Fig. 53. × 55

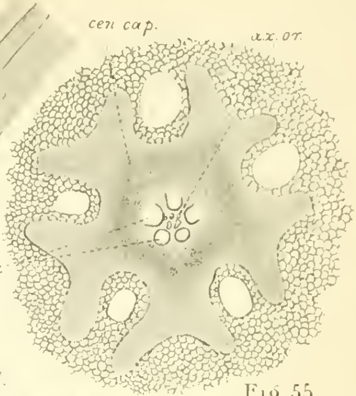


Fig 55 × 40

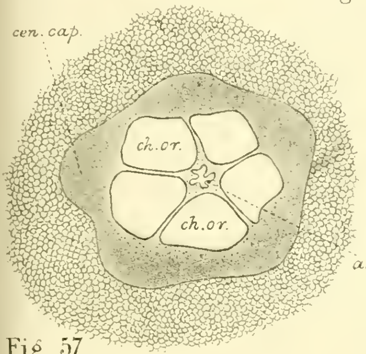
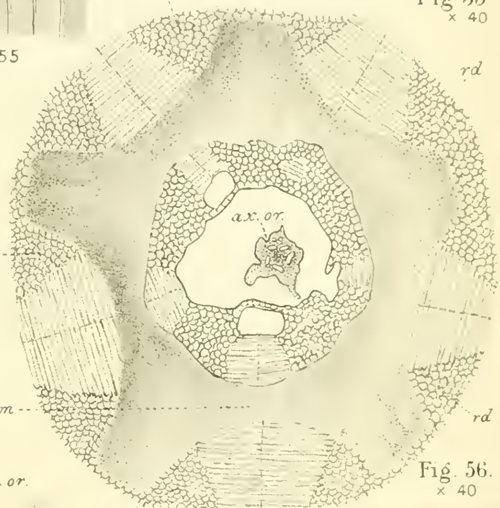


Fig. 57. × 40



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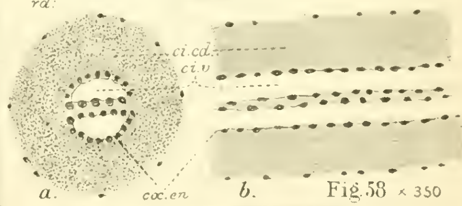

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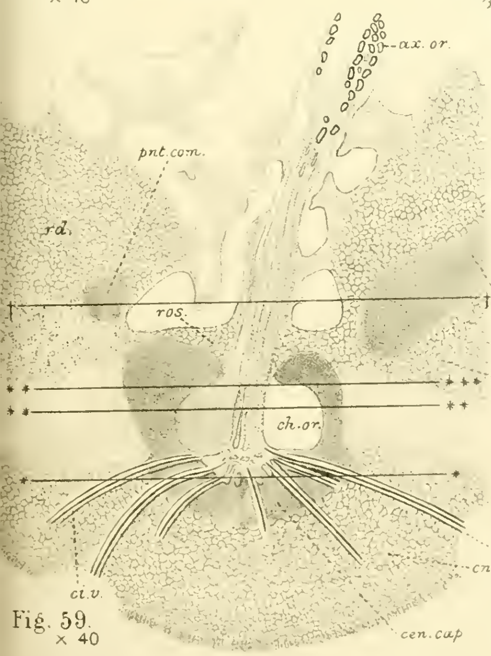

Fig. 59. × 40

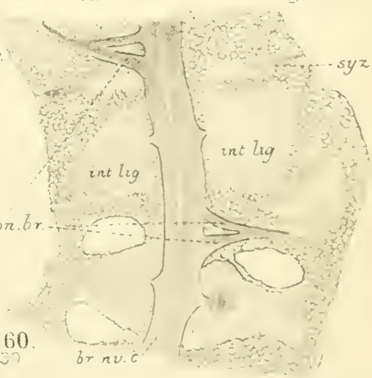

Fig. 60.

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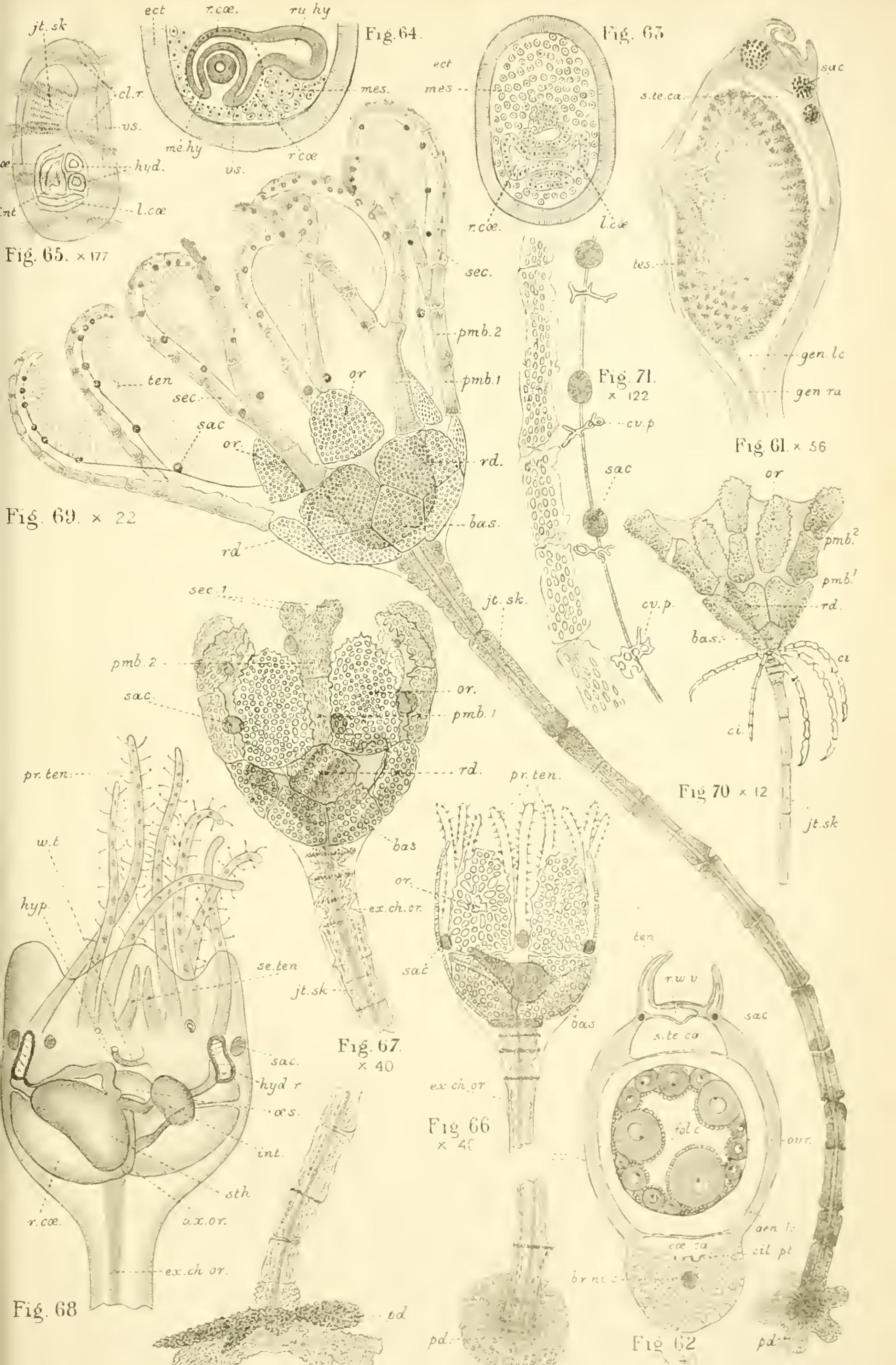
Fig. 64.
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